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General Info
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Inf. Div., CWS Tech. Comd., H.A.
HISTORICAL SKETCH OF EDGEWOOD ARSENAL.
by
Lieut. Col. William McPherson.

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Major General William L. Sibert,
Director, Chemical Warfare Service,
Washington, D. C.

Dear Sir:-

Complying with the request contained
in a letter from your office bearing the signature
of F. E. Breithut, Major, United States Army, under
date of November 30, 1918, there is herewith trans-
mitted ⁶ "An Historical Sketch of Edgewood Arsenal",
compiled by Lieutenant Colonel ¹⁹ William McPherson.

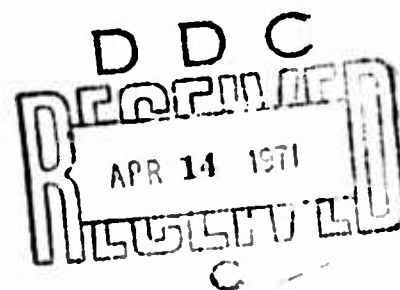
Respectfully submitted,

Commanding Officer, Edgewood Arsenal.

Edgewood Arsenal,
Baltimore, Maryland,
March 1, 1919.

(11) 1 Mar 19

(12) 127p.



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Info. Div., GWS Tech. Cond., J.A.G.

This report consists of an account of the inception of Edgewood Arsenal together with a brief statement of the development of the various projects included under its administration . It is presented in as non-technical language as possible and is intended for the general reader. Separate technical reports on each of the projects included under the Arsenal have been prepared for the use of the engineering specialist.

(B)

Edgewood Arsenal acknowledges with grateful appreciation the assistance rendered by various representatives of the Allied Nations, and especially by the following: Captain Raoul E. Hankar, of the French High Commission; Mr. W. Gordon Carey, and Mr. T. W. D. Gregory, representatives of English firms engaged in large scale production of toxic gases; Major G. M. Brightman, of the British Army; and Lieutenant-Colonel S. J. M. Auld, M.C., Officer Commanding British Gas Warfare Commission. Lieutenant-Colonel Auld arrived early in November 1917, bringing with him a rich experience in the problems involved in gas warfare, and with the exception of a brief interval remained until the close of the War, co-operating in an effective way and catalyzing the entire gas warfare program.

C

CONTENTS :

An Historical Sketch of the Development of Edgewood Arsenal;	.... 1
Total Production of Toxic Material;	....73
Total Number of Shell and Other Containers Filled;	....75
Procurement of Raw Materials	....77

.

A P P E N D I X

Properties of Certain Materials Used in Gas Warfare	.... 1
List of Edgewood Arsenal Plants for the Manufacture of Toxic Gases.	.... 4
Copy of Extract from Order No. 54	.... 6
Copy of Official Letter Establishing Gunpowder Reservation	.... 7
Copy of General Orders No. 62	.... 9
Copy of General Order No. 7	.... 12
Organization Charts	.... 13
Map of Edgewood Arsenal Grounds at Edgewood, Maryland	.... 22
Index	.... 23

AN HISTORICAL SKETCH OF THE DEVELOPMENT

OF

EDGEWOOD ARSENAL

Beginning
of Gas
Warfare

1. On April 22, 1915, the Germans launched their first gas attack. This action came as a complete surprise to the Allied Nations and was attended by disastrous results. Other attacks shortly followed, leaving no doubt but that the Germans intended to utilize toxic gas to the full limit of its possibilities. The adoption of this new agent of warfare by the Germans made it necessary for the Allied Nations to employ like tactics; and from that time until the last shot was fired, November 11, 1918, toxic gas played an ever increasing part in the battles waged between the Central Powers and the Allied Nations.

Status of
Gas War-
fare in
U.S., when
War was
Declared

2. Nearly two years elapsed between the date of the first gas attack and that of the Declaration of War by the United States. Unfortunately, but little attention had been given to the general subject in this country during the interval. Some information had been collected by our overseas military observers, and this had been referred to the War Department in Washington. Certain problems involved were referred at the time to the Picatinny Arsenal, but the work had been held in

Problems
of Gas
Warfare

abeyance pending the development of a suitable gas mask in order to insure safety to those engaged in the study of the highly toxic materials.

3. At the date of the entry of the United States into the struggle, gas warfare was on a thoroughly established basis. Both the Central Powers and the Allied Nations recognized its great possibilities, and each was striving to take whatever advantages might accrue from its use. Immediately, therefore, upon the Declaration of War, the United States found itself faced with all the problems connected with its development. Suitable gas masks for the protection of our troops had to be devised; methods for the production of toxic gases on a large scale had to be worked out and put into operation; gas shell, as well as the necessary machinery for filling these shell with toxic materials, had to be developed. The enormity of the problems was foreseen. Gases, the preparation of which even in very small quantities was often prohibited in laboratories because of their highly toxic character, were now to be prepared in quantities of many tons daily, loaded into shell and shipped to our armies in France.

4. At this time the War Department did not have available the personnel and facilities for carrying on the research necessary for the development of gas warfare. The only laboratories at all adapted for this sort

**Research
Work As-
signed to
the Bureau
of Mines.**

of work were those connected with the different arsenals; and these were already overcrowded with their own problems. In February, 1917, the Bureau of Mines, anticipating the Declaration of War by the United States and cognizant of the fact that the experiences gained by the Bureau in an extended study of mine gases would be of value in the investigation of this larger question, offered its services to the War Department. Later, this offer was accepted, and to this Bureau was assigned the task of carrying on the necessary research work.

**Assignment
of
Problems**

5. The work connected with the fabrication of gas masks and gas shell, with the production of toxic material, and with the development of a filling plant suitable for loading shell with this material was assigned as follows:

Gas Masks	*	*	Surgeon General's Office
Gas Shell	*	*	Artillery Ammunition
			Section, Ordnance De-
			partment.
Toxic Gas	*	*	Trench Warfare Section,
			Ordnance Department
Shell Filling			
Machinery	*	*	Trench Warfare Section,
			Ordnance Department.

In carrying out the work originally assigned to the Trench Warfare Section, Edgewood Arsenal was developed. The function of the Arsenal, therefore, has been twofold:

- (a) The procurement of the necessary toxic gas supplies, either by direct purchase from existing chemical firms or by the building and operating of Government plants, and

(b) The loading of this material into shell.

A Gas
Filling
Plant
Authorized

6. At the beginning the work was under the direction of Captain (now Lieutenant-Colonel) E.J.W. Ragsdale, who was then the head of the Trench Warfare Section. In June, 1917, General Crozier, then Chief of the Ordnance Department, approved the general proposition submitted by Captain Ragsdale of building a suitable plant for filling shell with toxic gas. Early in August, Captain Ragsdale placed Captain (now Lieutenant-Colonel) Edwin M. Chance in charge of the work connected with the preparation of plans and specifications of the proposed plant, which was designated as the United States Filling Plant.

Develop-
ment of
plans for
Filling
Plant

7. A study of the problems involved revealed the fact that the operation of filling a shell with toxic gas (which is really a liquid and never a gas, at least under the conditions under which it is loaded into shell) is similar, in a way, to that of filling bottles with carbonated water. In the development of plans for the filling plant many suggestions were, therefore, obtained from a study of the apparatus used in commercial bottling plants. It was necessary in the development of these plans to keep in mind not only the large number of shell to be filled, but also the highly toxic character of the filling material to be used. It was essential, therefore, that the work of filling and closing the shell

Develop -
ment of
Plans for
Filling
Plant

should be done by machinery insofar as it was possible, and that the operation be carried out in a thoroughly ventilated room or tunnel, arranged in such a way that the machinery contained in the tunnel could be operated from the outside, thus insuring safety to the workers. Special precautions would have to be taken also in order to close the shell so as to prevent leaks; for many weeks would elapse between the time of filling the shell and that of their use on the battlefield, during which time escaping gas would be a constant menace, especially in overseas transportation. To meet these requirements, it was decided to use a standard taper pipe thread, and to devise automatic machinery for closing the shell. It may be inserted here that the final results secured were admirable, as is evidenced by the fact reported by the Quartermaster Officer at Vincennes on November 15, 1918, that not a single leaky shell had been found among the 200,000 shells received at Vincennes up to that date. It was also evident that the plans would have to provide for a thoroughly efficient ventilating system, and for suitable equipment for conveying the shell through the filling tunnel and thence to the shell dump where they could be tested, painted and packed, ready for shipment. A refrigeration plant would also be a necessity whenever a low boiling liquid were used as a filling material.

Phosgene, for example, is a gas at ordinary temperatures, but condenses to a liquid at 8° Centigrade. In filling shell with phosgene, therefore, it would be necessary to keep both the phosgene and the shell at a temperature considerably below 8°C. in order to maintain the material in liquid form until the shell are filled and closed, and this would require strong artificial cooling.

8. In place of one large filling plant, it was thought best to build two or more smaller plants, each of which in turn would be made up of units radiating from a central refrigeration plant which would serve all the units. Each unit could then be fitted with machinery adapted for filling shell of a definite size; moreover, an accident in one of the units would in no way impair the working of the remainder.

Filling
Plant to
be Built
in Units

9. The following firms co-operated in an efficient way in working out the details of the plans for the filling plant and in the fabrication of the necessary machinery:

Co-operat-
ing Firms

Waterbury-Farrell Foundry & Machine Company,
The Reynolds Machine Company,
The Liquid Carbonic Company,
The Karl Kieffer Machine Company,
The Spray Engineering Company,
The Triumph Ice Machine Company,
The Link-Belt Company.

10. While the plans for the filling plant were being worked out and perfected, the Bureau of Mines was busy

**Decision
Reached to
Use Chlor-
picrin and
Phosgene**

with the problems involved in the development of commercial methods for the manufacture of toxic material. A number of different gases had been used by the warring nations up to the time of the entry of the United States into the War, and two of these, viz: phosgene and chlorpicrin, had become more or less standard. In order that there might be no delay incident to extended research, it was decided to utilize these two gases, pending the discovery, if possible, of newer and more effective material. Efforts were concentrated, therefore, upon the development of the commercial methods for their manufacture.

**Method for
Preparing
Phosgene**

11. Fortunately, considerable information was available concerning the methods of manufacture of phosgene. This compound had been used for a number of years previous to the outbreak of the War, in the making of certain dyes, especially methyl violet, and had been prepared in Germany for this purpose. The process of manufacture, however, had never been developed in the United States. It was known that the gas could be prepared in the laboratory in a number of different ways. Apparently, the most economical of these for the large-scale production consisted in passing a mixture of the two gases, carbon monoxide and chlorine, over carbon. Under the proper conditions, these two gases, when brought into contact with carbon, unite directly to form phosgene. The chemist expresses the

combination in this way:



Assistance
Rendered
by Oldbury
Electro-
Chemical
Company

The reaction, however, is a delicate one, and its application to large-scale production required extended investigation. Luckily, for some months previous to the War, the Oldbury Electro-Chemical Company of Niagara Falls, New York, had been working on the problems involved, in the hope that the carbon monoxide formed in the phosphorus furnaces operated by the Company might be utilized in the manufacture of phosgene. Shortly after War was declared, this Company offered to assist the Government in the development of a commercial method for the manufacture of the gas. As a result, the experimental laboratory of the Company was enlarged and equipped with additional apparatus. Considerable phosgene was prepared in this period of experimental development and was sent gratis to the Bureau of Mines and utilized in the research work being carried on by the Bureau.

Experi-
mental
Plant for
Producing
Phosgene

12. This experimental laboratory proved to be of the greatest service. Not only were many of the details of the commercial process of manufacture worked out here, but it served also as a training school for the men who subsequently were to take charge of the operation of the large chemical plants under consideration. Moreover, the laboratory developed until the Government felt justified

Contract
for
Phosgene

in leasing it for the production of phosgene until the commercial plants were ready for operation. The lease was for a period of six months, beginning March 1, 1918. Before the six months had expired, however, the large-scale plants were ready for operation; accordingly, the experimental plant was closed down and the operating force transferred to the large-scale plants.

13. By November 1, 1917, sufficient progress had been made to justify the building of plants for the manufacture of phosgene on a large scale. The Oldbury Electro-Chemical Company was pre-eminently the one to undertake this work; for it not only had far more experience than any other firm in the production of phosgene, but also had at hand the raw materials, the carbon monoxide being obtained from the phosphorus furnaces operated by the Company, and the chlorine from the plant of the Electro Bleaching Gas Company, located only a few yards distant. Accordingly, a contract was entered into with the Oldbury Electro-Chemical Company to build and operate a phosgene plant with the capacity of 20,000 pounds per day. Inasmuch as the material had never been made on a large scale, it was impossible to forecast with accuracy the cost of manufacture; accordingly, the Company would only undertake the work on a cost plus profit basis. This plant when constructed was designated the "Niagara Falls Plant of Edgewood Arsenal".

Laboratory
Preparation
of
Chlorpicrin

14. The laboratory process for the manufacture of chlorpicrin was also well known at the time of the Declaration of War. This process consists in passing live steam through a mixture of picric acid and ordinary bleaching powder (the so-called "Chloride of Lime" of the druggist) under well regulated conditions. The reaction is carried out in a still of suitable dimensions, to which is attached a condenser. The resulting chlorpicrin, together with steam, passes out of the still and is condensed. Inasmuch as chlorpicrin and water are practically insoluble in each other, the mixture of the two, on standing, separates into the two constituents. The chlorpicrin, being heavier, settles to the bottom of the condenser and is sufficiently pure to use without further treatment.

15. The problem at hand was the development of this method so as to make it applicable to large-scale production. The experimental work bearing upon this problem was conducted at three different plants, viz:

The American Synthetic Color Company, Stamford,
Connecticut.
The Dow Chemical Company, Midland, Michigan.
The Semet-Solvay Company, near Syracuse, New
York.

Considerable material was produced in these experimental plants and was sent to the Bureau of Mines for further study. In all of these plants the production was con-

Development
of Method
for large-
Scale Pro-
duction of
Chlorpicrin

ducted on a semi-commercial scale. Information was desired as to the size and character of the still best adapted for the work. Our own war program called for a large quantity of chlorpicrin, and in addition, arrangements had been made whereby the United States was to furnish the French with a sufficient amount to meet the needs of their Army. Because of the large quantity to be prepared, it was desired, therefore, to use as large a still as was practicable. The question arose as to whether or not in the operation of large stills the temperature necessary for the reaction could be maintained by simply passing steam through the mixture of raw materials; if it could not, then steam-jacketed stills would have to be used. There also was a difference of opinion as to whether or not the still should be provided with stirrers. The results of the experiments showed that either form of still would undoubtedly do the work, the only question being as to the relative efficiency of the two types. It may be added here that both forms of stills were ultimately used, and that the simpler form - that without steam jacket or stirrers - proved to be the most efficient.

16. By December 1, 1917, sufficient information was at hand to justify large-scale production. The aid of a number of companies was solicited, but only one of

Contract
for
Chlorpiorin

these, namely, The American Synthetic Color Company, was willing to undertake the work. It was known that the Company was not in the best financial condition. Most of the development work, however, in connection with the process of manufacture of chlorpiorin had been done at this plant; it was thought, therefore, that with Government aid the Company would be able to accomplish the undertaking. In accordance with the terms of the contract the Government was to pay the cost of special apparatus required to an amount not exceeding \$100,000.00. This plant later was designated the "Stamford Plant of Edgewood Arsenal".

Site for
Filling
Plant
Selected

17. In the meanwhile, the plans for the new filling plant were being rapidly developed, and it became urgent that a suitable location for this plant be selected. It was intended at first to locate it on Kent Island, Maryland, but Congress failed to approve the plan. Later, a large tract of land, comprising 35,000 acres near Aberdeen, Maryland, was taken over by the United States Government and set aside as a proving ground under the President's Proclamation, dated October 16, 1917. This ground was well adapted as a suitable site for the proposed shell filling plant. It was in an isolated district and relatively near the embarkation ports. Moreover,

railroad transportation could easily be secured, since the main line of the Pennsylvania Railroad between Baltimore and Philadelphia bordered on the tract; water transportation was likewise possible, since the tract bordered also on the Bush River, which leads into Chesapeake Bay. It was definitely decided, therefore, to utilize a portion of this ground as a site for the plant, and approximately 3,400 acres on that portion of the land known as "Gunpowder Neck" was set aside for this purpose (see map-Appendix, page 22). The location and extent of the grounds thus to be utilized, as fixed by an order issued by Brigadier-General C. B. Wheeler under date of April 2, 1918, (for copy of order see Appendix, page 7), are as follows:

**Work Begun
on Filling
Plant**

"That part of the Aberdeen Proving Ground which is bounded on the North by the Pennsylvania Railroad, on the West by the Bush River, and on the East by Gunpowder River, and on the South by a line as indicated on the map accompanying the order."

Because of the location the entire project was at first referred to in official orders under the title of "Gunpowder Reservation" or "Gunpowder Neck Reservation".

The railway station bordering on the tract of land is known as "Edgewood"; hence the name "Edgewood Arsenal" (page 23) which was later applied to the entire project. The site for the filling plant having been approved, work was immediately begun. The construction of a railroad spur,

connecting the grounds with the Pennsylvania Railroad, was started on October 24, 1917, and on November 15, 1917, actual construction work was started on Filling Plant #1.

18. It was the original intention to interest existing chemical firms in the manufacture of the required toxic materials, with the hope of obtaining from such firms the entire supply required. As the work developed, however, difficulties arose in carrying out this program. The manufacture of such material at private plants necessitated its shipment to the filling plant at Edgewood for filling into shell, and the transportation of large quantities of highly toxic gases would naturally be attended with great danger. After due consideration, the Director-General of Railroads ruled that all such shipments must be made by special train movements - a very expensive method of transportation. Still more serious objections, however, were encountered in the efforts to enlist the co-operation of existing firms. It was recognized by these firms that the manufacture of such materials would be attended by very great danger; that the work would be limited to the duration of the War; and that the processes involved, as well as the plants necessary for carrying out these processes, would have little post-war value. Moreover, such firms as had the personnel and equipment for carrying on this kind of work were already overcrowded with orders;

Total
Supplies of
Toxic Gas
not Procur-
able from
Existing
Firms

Government
Chemical
Plants De-
cided Upon

with few exceptions, therefore, they were unwilling to undertake work of this character.

19. As soon as it became evident that the necessary supplies could not be obtained in whole from existing firms, steps were taken immediately to build certain Government chemical plants at Gunpowder Reservation in connection with the United States Filling Plant. By December 1, 1917, it had been definitely decided to build two such plants, one for the production of chlorpicrin and one for the production of phosgene. Contracts had already either been signed or agreed upon with private firms for the production of a limited amount of each of these products; the building of Government plants would not only greatly add to the production, but would also guard against a complete shut-down in case of accidents in one of the plants. The Government plants located at Gunpowder Reservation were later designated the "Edgewood Plants of Edgewood Arsenal".

20 The type of still selected for the Edgewood chlorpicrin plant was the simpler form (page 11) of the riveted boiler type. A number of these, 8' x 18', were available, and one was sent immediately to the plant of the American Synthetic Color Company at Stamford, Connecticut, and an experimental unit erected there. The operation of this unit, aside from the chlorpicrin prepared, resulted in furnishing a great deal of valuable information bearing

Development
of Plans for
Edgewood
Chlorpicrin
Plant

on the final design of the Edgewood Plant. Considerable trouble resulted from the frothing of the contents of the still, some of the solid matter passing over and contaminating the final product. This difficulty was overcome by beating down the foam, whenever it passed beyond a certain height, with a spray of steam, or better, of cold water admitted through appropriate pipes placed in the head of the still. The plans as finally prepared called for a steel building, 138' x 400', (floor space about 1-1/4 acres). The equipment consisted of 19 large stills (20 had been ordered, but one was sent to the Stamford Plant as noted above) for carrying out the reaction together with the necessary machinery for introducing the raw material into the still, as well as for condensing the product and separating it from the water with which it is mixed when first prepared. It was finally decided, however, to erect only 10 of these stills and to use the remainder for storage tanks. This arrangement left about one-half the building free, and this was later utilized for housing the plant for the generation of ethylene required in the manufacture of mustard gas. In the earlier experiments the free picric acid was used. It was found later that the work could be greatly simplified by first converting the picric acid into calcium picrate through the action of calcium hydroxide, sufficient



View of site of plant for the manufacture of chlorpicrin as well as of the finished plant. Both views were taken from the same spot, the top view being taken February 6, 1918, and the bottom one on May 21, 1918.

Process of
Manufacture
of Chlor-
picrin at
Edgewood

water being used in the operation to dissolve the resulting calcium picrate. This solution is then run into a strong iron container (the so-called "acid egg") and forced into the still by compressed air.

21. Construction on the Edgewood chlorpicrin plant began on January 25, 1918, and operation on June 9, 1918.

22. As finally developed, the process of manufacture is carried out in the following way: The bleach is mixed with water and stirred until a cream is formed. This cream is then pumped into the still along with the solution of calcium picrate which is forced in by compressed air. The raw materials thereby become thoroughly mixed together. A current of live steam is then admitted at the bottom of the still. As the temperature of the mixture rises, the reaction gradually begins, and at 85° C. the chlorpicrin rapidly passes over together with steam, is condensed by passing through a multitubular condenser and then stored in large tanks. The chlorpicrin, being insoluble in water and heavier, gradually sinks to the bottom of the tank and is drawn off, ready to be filled into shell. The picric acid and bleach used in the process are employed in the ratio of one part, by weight, of picric acid to approximately 10 parts of bleach. The yield of chlorpicrin at the Edgewood Plant averaged about 1.6 times the weight of picric acid used. The yield at

Process of
Manufacture
of Chlor-
picrin at
Stamford

the Stamford Plant was slightly less.

23. The process as carried out at the Stamford Plant (pages 11-17) was practically identical with that of the Edgewood Plant. The stills, however were much more elaborate, being steam-jacketed and provided with stirrers. When the plant began operation, it was found that neither the jacket nor stirrers were of any assistance, so that the stills were operated like those of the plain boiler type. Inasmuch as the French had withdrawn their request for chlorpicrin, only 9 stills were erected; those remaining of the lot purchased for the plant were later shipped to Edgewood and there utilized in the manufacture of mustard gas.

Assistance
Rendered
by Oldbury
Electro-
Chemical
Company

24. In the development of the Edgewood phosgene plant, great assistance was rendered by the Oldbury Electro-Chemical Company. This company not only turned over for Government use the results of all experiments conducted in the experimental plant operated by the Company, but also the proposed plans for their large-scale plant. There were also available the reports of the methods of manufacture used abroad.

25. The conditions under which carbon monoxide and chlorine unite to form phosgene (pages 7-8) had been worked out at the experimental plant referred to above. The chlorine supply was provided for. The difficult

**Plans for
Producing
Carbon
Monoxide**

problem remaining unsolved was that of securing an adequate amount of pure carbon monoxide. It was known that this gas can be readily made on a limited scale by passing oxygen over hot carbon. The reaction, however, is strongly exothermic - which is only another way of saying that a great deal of heat is evolved. If the reaction is carried out on a large scale, this heat becomes so intense as to make it very difficult, if not impossible, to keep it under control. It was proposed to overcome this difficulty by substituting for pure oxygen a mixture of oxygen and carbon dioxide. The latter gas, like oxygen itself, unites with hot carbon to form carbon monoxide, but the action is endothermic, that is, heat absorbing. It was thought, that by mixing the oxygen with the proper amount of carbon dioxide the temperature could not only be kept within the proper limits, but additional amounts of carbon monoxide could be secured. The plan as proposed, when put into practical operation, proved to be a complete success and served to furnish a pure grade of gas in the quantity desired. The reaction was carried out in large gas producers built by the United Gas Improvement Company.

26. It was proposed to obtain the oxygen required in the process by separating it from the air

**Production
of Oxygen
and Carbon
Dioxide**

through the agency of a liquid-air machine, and for this purpose there were secured two Claude machines, each guaranteed to furnish 100,000 cubic feet of oxygen, 99.6% pure, in 24 hours. The plans provided for the preparation of the requisite amount of carbon dioxide by the combustion of coke. The impure gas so obtained was to be purified first by washing, and then the process of purification completed by absorbing the gas in a solution of potassium carbonate, which product on heating evolves pure carbon dioxide. The details of this process were worked out by the Carbondale Machine Company, Carbondale, Pennsylvania, and the necessary equipment for carrying out this process was obtained from this Company

**Plant to
be Built
in Units**

27. It was decided to build the phosgene plant in units, each of 10,000 pounds capacity. Four of these units were to be housed in one building. This arrangement would admit of indefinite expansion. The plans were completed and work of construction begun on March 1, 1918.

28. As finally developed, the process of manufacture of phosgene at the Edgewood Plant is carried out in the following way: Carbon monoxide, prepared as described in paragraph 25, together with the requisite amount of chlorine, is passed into catalyzer boxes (8'

**Process of
Manufacture
of Phosgene
at Edgewood**

long x 2'9" deep x 11" wide) which are made of iron, lined with graphite, and filled with a porous form of carbon. Two sets of these boxes are used. In the first the union between the carbon monoxide and chlorine is about 80% complete. Operation is brought to completion in the second catalyzer box, which is surrounded by hot water. The resulting phosgene is then dried by sulphuric acid, is condensed by passing it through lead coils surrounded by refrigerated brine (phosgene boils at 8° C.), and run into large iron cylinders holding about 1,650 pounds of material. In this form it is either sent overseas in bulk, or to the filling plant for loading into shell.

**Bound Brook
Phosgene
Plant**

29. About January 1, 1918, information was received that the Frank Hemingway, Inc., at Bound Brook, New Jersey, had been conducting researches extending over a period of several months on the production of phosgene. It was learned also that the Company was operating an experimental plant and furnishing phosgene to certain dye manufacturers from the output of the plant. The Company, learning of the needs of the Government, offered to enter into a contract to build and operate a large-scale phosgene plant. Inasmuch as the process of manufacture employed by the Company was a secret one, the Government was unwilling to enter into a contract without definite information con-

cerning the process. Accordingly, a committee, consisting of Dr. M. C. Whitaker and Captain (now Lieutenant-Colonel) William McPherson visited the experimental plant and investigated the process. The report of the committee being favorable a contract was made by the Ordnance Department with the Company on a cost-plus-profit basis, to build and operate a plant with the capacity of 10,000 pounds per day. Construction on the plant was begun February 2, 1918, and phosgene was first manufactured there on May 17th. This plant was known as the "Bound Brook Plant of Edgewood Arsenal".

30. The Government now had in process of construction three phosgene plants, namely, the Niagara Falls Plant, the Edgewood Plant and the Bound Brook Plant. The processes of manufacture in all of these were practically identical except in the method of generating carbon monoxide. In the Niagara Falls Plant this gas was obtained as a by-product in the manufacture of phosphorus; in the Edgewood Plant it was prepared by passing a mixture of carbon dioxide and oxygen over hot charcoal; while in the Bound Brook plant it was prepared by passing oxygen alone over the charcoal, this method being possible because only a limited supply of the gas was required. The Bound Brook Plant also utilized a form of carbon in the catalyzer boxes different from that used in

Methods
for
Making
Phosgene
Contrasted

the other two plants.

31. The entire project located at Gunpowder Neck, together with all plants built by the Government at other localities for the manufacture of toxic gas, remained under the command and administration of the Trench Warfare Section until March 6, 1918. On that date Lieutenant-Colonel William H. Walker, then Assistant Director of the Gas Service and Chief of the Chemical Service Section, National Army, was appointed Colonel in Ordnance Department of the National Army and made Commanding Officer of Gunpowder Reservation, (War Order #54, paragraph 42 Appendix, page 6). The order provided that the headquarters of the Reservation be changed from Washington to Baltimore; and that Colonel Walker should report directly to the Chief of Ordnance. The effect of this order, therefore, was to withdraw the Reservation entirely from the administration of the Trench Warfare Section, and to make it a separate unit in the Ordnance Department. A subsequent order was issued by the Acting Chief of Ordnance on April 2, 1918, (see Appendix, page 7), outlining more in detail the scope of the work at the Reservation and the method of its administration. Since this order provided that the project was to be administered in accordance with the rules and regulations governing the administration of Arsenals, the title "Gunpowder Reservation" was later changed to that of "Edgewood Arsenal", in accordance with General

Change in
Adminis-
tration

Name
Changed to
"Edgewood
Arsenal"

Offices
Changed to
Baltimore

Chemical
Warfare
Service
Organized

Order #7, issued under date of May 4, 1918, (see Appendix, page 12 for copy). Early in April the offices of the Reservation were moved from Washington to Baltimore, while those in immediate charge of the Construction work took up their quarters at the Reservation itself. The Arsenal remained as an integral part of the Ordnance Department until June 28, 1918. On this date General Orders # 62 (see Appendix, page 9 for copy) was issued by the War Department. This order provided that the Gas Service of the Army be organized into a Chemical Warfare Service. The order also provided that Major-General William L. Sibert be relieved from duty as Director of the Gas Service, and be detailed as Director of the Chemical Warfare Service. The entire organization of Edgewood Arsenal was thereby transferred from the administration of the Ordnance Department to that of Chemical Warfare Service, reporting directly to Major General Sibert.

32. Previous to the appointment of Colonel Walker as Commanding Officer of Edgewood Arsenal, the Ordnance Department, at the request of the Trench Warfare Section, had entered into four contracts for the manufacture of toxic materials. These projects are as follows:

- (a) Plant located at the Oldbury Chemical Company, at Niagara Falls, N.Y. (page 9)
- (b) Plant located at the American Synthetic Color Company, Stamford, Conn. (pages 11 & 12)
- (c) Plant located at Frank Hemingway Company,



General view of the Niagara Falls Plant of Edgewood Arsenal.
Capacity 20,000 pounds of phosgene daily.

Inc., Bound Brook, N. J. (pages 21 & 22)

- (d) The sinking of 17 Brine Wells, about 3 miles from the plant of the Dow Chemical Company, Midland, Mich. (pages 38 & 39)

The above were Government plants inasmuch as they were financed either partly or wholly by the Government. Their operation, however, was conducted by the contracting companies. Their proper administration necessitated the presence at each plant of a representative of the Government together with such assistants as were necessary to look after the Government's interests. At first, these plants were under the administration of the Trench Warfare Section but had no connection with the United States Filling Plant at Edgewood. However, under the order issued by the Acting Chief of Ordnance under date of April 2, 1918, (see Appendix, page 7) they were made a part of Edgewood Arsenal and included under the administration of the Commanding Officer of the Arsenal. Similar plants originating subsequent to the order of April 2nd have likewise been under the administration of the Arsenal. These are known collectively as "the outside plants" to distinguish them from similar ones located at Edgewood and known as "the Edgewood plants".. Each of these outside plants is designated by the name of the city or town at which the plant is located. A list of all the chemical plants operated by Edgewood Arsenal, together

Outside
Plants

with the names of each and the nature of the project, is given on page 4 of the Appendix.

33. During the winter months of 1917 and 1918 the work of construction at Edgewood was rapidly carried forward. Notwithstanding the extreme severity of the winter, the delays incident to lack of transportation, the scarcity and general inefficiency of labor, construction continued night and day, and rapid progress was made. Temporary barracks were built for the workmen, officers' quarters were erected, and a temporary hospital with a capacity of 50 beds pushed to completion. A power plant was built in connection with Filling Plant #1. This had an electrical capacity of 5,000 K.W. and was designed to furnish power to the filling and chemical plants as well as for the general purposes of the Arsenal. To obtain the necessary water for operating the plants, a system was installed with a capacity of 9,500,000 gallons per day. The water was pumped from the Bush River, nearby, to the plants through a wooden pipe, 3 feet in diameter. The filling plant and the power house were constructed of tile. When the plans for the chemical plants were ready, it was found that steel buildings could be secured, and it was decided to use steel whenever it was possible; for this material, like the tile, is fireproof and has the additional advantage in that much of the work of

Construction
during
Winter of
1917 - 18

Type of
Con-
struction

fabrication can be completed before shipment, and thus less labor would be required at Edgewood where competent labor was hard to secure; moreover, the steel could be transported more readily than the raw materials used in the tile construction, and the sections being bolted together could be taken apart and salvaged to greater advantage in case this was desired at the close of the War.

34. Early in March, 1918, Filling Plant #1 had been completed to such an extent as to admit of limited operation. The plant was made up of four wings or units radiating from a common center. Near the center was housed a refrigeration plant and adjacent to it a power house. As completed, each of the units of the plant is composed, in brief, of the following:

Description
of Filling
Plant

- (a) The room and apparatus necessary for chilling the shell.
- (b) Filling tunnel provided with machines for filling and closing the shell.
- (c) An appropriate ventilating system together with towers for removing any toxic material which escapes in the filling process.
- (d) Appropriate devices for receiving, cooling, and mixing the toxic material with which the shell are to be filled.

35. With phosgene as the filling material the process of filling and closing the shell is briefly as follows: The empty shell, after inspection, are loaded on trucks together with the appropriate number

Process of
Filling
and Clos-
ing Shell

of encased explosive charges (the so-called "boosters") which screw into the top of the shell and thereby close it. These trucks bearing shell and boosters are then run by electric storage battery locomotives to the filling unit. Here the empty shell are transferred by hand to a conveyor, after which the conveyor bearing the shell slowly moves through a room kept cold by refrigeration. Approximately 30 minutes is required for this transit, during which time the shell are cooled to a temperature of about 0° F. These shell are then transferred to shell trucks, each truck carrying 6 shell. The truck, thus loaded, is then drawn through the filling tunnel by means of a chain haul operated by an air motor to the filling machines. Here the phosgene, kept in liquid state by refrigeration, is run into the shell by automatic machines, so arranged that the 6 shell are at the same time automatically filled to a constant void. The truck then carries the filled shell forward a few feet to a small window, at which point the boosters are inserted into the nose of the shell by hand. The final closing of the shell is then effected by motors operated by compressed air. The filling and closing machines are all operated by workmen on the outside of the filling tunnel. The air in the filling tunnel is constantly withdrawn and the tail gases are washed in stoneware towers by appropriate chemical

Capacity of Filling Plant

(a) Two wings adapted to fill 4.7" and 5" shell with either phosgene or a mixture of chlorpicrin and stannic chloride (the so-called N.C.)
 9,000 per day.

(b) Two wings adapted to fill 75 mm. shell with either phosgene or N.C. 15,000 per day.

(c) Later an annex was added, adapted to fill Livens drums, with a capacity of . . .
 900 per day.

Edgewood Arsenal Ready for Operation



U.S. FILLING STA. 3-9-18.
LABOR CAMP, FROM WATER TOWER
LOOKING TOWARDS MESS HALL.
R3

426

View of typical temporary barracks. These were built of wood, lined on the outside with tarred paper, and on the inside with composition board.

the middle of March, therefore, Edgewood Arsenal was ready for business. The necessary shell and boosters, however, were not available, and in fact did not become available for many weeks more, and then only in limited quantities.

**Chemical
Laboratory
Planned**

38. As soon as it was decided to build Government plants at Edgewood for the production of toxic materials, steps were taken to provide for a suitable chemical laboratory, properly equipped and manned to solve the many problems constantly arising in the operations of a chemical manufacturing plant.

**Description
of
Laboratory**

39. The plans for the laboratory were begun about January 1, 1918, and steps were taken at once to place orders for the necessary chemicals, apparatus and books. Work on the construction of the laboratory was begun April 7, 1918, and the first chemical work carried on was on June 18, 1918. The laboratory is built of hollow tile and contains 21 rooms, each of which was designed for carrying on special work. Before the laboratory was complete, so many problems arose in the development of the methods of manufacture of various toxic material that provisional laboratories were established at the following localities:

Bureau of Standards
Geophysical Laboratory
Ohio State University
Johns Hopkins University

Washington, D. C.
Washington, D. C.
Columbus, Ohio.
Baltimore, Md.

Inspection
Work

40. In addition to the regular Chemical work of the laboratory, there was later assigned to it certain inspection work of the Arsenal.

Work of
the
Laboratory

41. In connection with the routine control of the chemical operations in the various plants of the Arsenal, no less than 167,092 single chemical determinations were made. The investigations carried on in the laboratory dealt with all phases of the various activities of Edgewood Arsenal, and were submitted in the form of reports. The number of reports so issued is 460. It was due to the splendid work of this laboratory that the manufacturing plants for toxic gases were so promptly put upon a productive basis and their efficiency constantly maintained.

Large
Quantities
of Chlor-
ine Re-
quired

42. As the work progressed, the information from overseas indicated that much larger quantities of toxic gas would be required than was originally supposed. The manufacture of this amount of gas demanded an enormous supply of raw materials, and increasing attention was given to their procurement. Most prominent among these raw materials was chlorine, for this gas is not only used directly in wave attacks, but it is also essential for the production of nearly all the other toxic gases employed in warfare. Fortunately, it had long been used in the United States, and its manufacture was on a thoroughly established basis before War was declared. The pre-war production of chlorine averaged

Chlorine
Demand
and
Supply

Shortage in
Chlorine
Supply

How Best to
Increase
the Chlor-
ine Supply

about 900,000 pounds per day. The greater amount of this was utilized in the manufacture of bleach. Three of the existing plants were equipped for liquefying the gas, and had a total output of about 60,000 pounds per day. This pre-war production was somewhat in excess of the country's peacetime demands, and some of the existing plants were capable of a limited expansion. Moreover, in order to help out in the emergency, the paper companies agreed to use during the period of the War only half as much bleach as is ordinarily used in bleaching paper pulp, and this arrangement would add considerably to the supply available for war purposes. It was soon recognized, however, that even with these accessions to the amount available, large additions would have to be made to the chlorine output of the country in order to meet the proposed toxic gas requirements.

43. The question as to the best method for increasing the chlorine supply of the country was one to which a great deal of thought was given. The chief difficulty lay in the procurement of the necessary electrical power or the equipment required for generating this power. It would be necessary to utilize electrical equipment already completed or nearly so, as it was out of the question to wait for the complete fabrication of such machinery. A certain amount of electrical power was either available or could be made so in relatively short periods in different



View of the transformer station at the chlorine plant. The current received from the hydro-electric station at McCall's Ferry, Pa., at 68,000 volts is here reduced to 6600 volts.

How Best to
Increase
the Chlor-
ine Supply

places throughout the country. The chlorine, however, would have to be utilized at Edgewood, and its manufacture at points remote from this locality necessitated its transportation - a difficult and more or less dangerous undertaking when large quantities of gas were to be handled, to say nothing of the delays of transportation which seemed inevitable from the experience during the winter of 1917 - 1918. If the chlorine were generated at Edgewood, on the other hand, this transportation would be avoided. In its place, however, there would have to be transported raw materials used in its manufacture; but these materials, principally salt and coal, are easily transported, and differ from the chlorine in that they could be shipped and stored up in large quantities during the period of the year when transportation is easy, and thus guard against a possible shortage during the winter period when transportation is difficult, a fact of very great importance.

44. So far as transportation was concerned, therefore, the arguments were all in favor of locating a plant at Edgewood. If located there, however, new sources of electrical power would have to be developed. It was found that there was immediately available a rotary unit sufficient to generate an electrical current of 10,000 K.W. Moreover, an additional unit of this

Electric
Power
Available

capacity was under construction and could be made available within a few months. These two units would furnish sufficient electrical power to generate more than 200,000 pounds of chlorine per day (125 K.W. are required to generate 2,000 pounds of chlorine in 24 hours). The installation of this equipment would cause some delay. It developed, however, that sufficient current for operating the plant in the interim could be obtained by extending a transmission line from Edgewood, a distance of about 10 miles, to the electric lines which tie up the hydro-electric power plant of the Pennsylvania Water & Power Company at McCall's Ferry, Pennsylvania, with the Consolidated Gas & Electric Light & Power Company of Baltimore, Maryland.

Decision
Reached
to Build
Chlorine
Plant at
Edgewood

45. Taking all the facts into consideration, and after a thorough investigation and discussion, it was decided to meet the situation by building a chlorine plant at Edgewood with a capacity of 200,000 pounds per day (2 - 100,000 pounds units). The Nelson Cell was selected for use in the proposed plant. Each of these cells is 13" x 32" x 80" in size, is operated by a current of 1,000 amperes and 3.8 volts, and has a capacity of 60 pounds of chlorine and 65 pounds of caustic soda per 24 hours. The engineering work in connection with the plant was assigned to the Samuel M. Green Engineering Company, Springfield, Massachusetts, and this Company was assisted by Mr. H. R. Nelson,

the inventor of the Nelson Cell. The plans when completed called for the following buildings and equipment:

**Description of
Plans for
Chlorine
Plant at
Edgewood**

- (a) THE BRINE BUILDING, in which the salt used in generating the chlorine is received, dissolved in water, and purified.
- (b) THE CELL HOUSE, composed of 2 buildings, each of which is divided into 4 rooms. Each room contains 6 banks of 72 cells each, and has a capacity of 25,000 pounds of chlorine per 24 hours, thus giving a total capacity for the entire plant of 200,000 pounds per 24 hours.
- (c) THE ELECTRICAL SUBSTATION. The current is received from the hydro-electric power plant at 68,000 volts and reduced at an outdoor transforming station near the cell plant to 6,600 volts; the substation contains the equipment necessary to further reduce this to 200 volts, and change it from alternating to direct current at approximately 260 volts.
- (d) THE BOILER AND EVAPORATION PLANT contains the necessary boilers and evaporators for concentrating the caustic solution received from the cells.
- (e) CAUSTIC FUSION BUILDINGS, in which the concentrated caustic solution obtained from the evaporation plant is evaporated to dryness, and the resulting caustic soda fused into solid form, ready for shipment.
- (f) LIQUEFYING PLANT, with provisions for liquefying 100,000 pounds of chlorine per day. The chlorine is pumped to the top of a tower by means of a Nash pump working in sulphuric acid. The tower is provided with a number of vertical pipes through which a flow of sulphuric acid is constantly maintained. The chlorine at the top of the tower is sucked into these pipes by the falling column of sulphuric acid. By the time it reaches the bottom of the pipe it is under a pressure of from

35 to 40 pounds per square inch, due to the weight of the falling column of sulphuric acid. The compressed gas is then cooled to about 30° C. under which condition it passes into the liquid state, and in this form is stored in strong iron cylinders.

In the main, the buildings comprising the chlorine plant consist of wood framework with expanded metal walls plastered on both sides with cement plaster. The only exceptions to the above type are the caustic fusion building, which contains steel framework in place of wood, and the substation, which is entirely fireproof, the walls being of tile and the roof of corrugated iron.

46. In order that an efficient operating force might be available upon the completion of the plant, arrangements were made with the Warner-Klipstein Chemical Company of Charleston, West Virginia, to use the chlorine plant of this Company, which was similar in construction to the proposed Government plant, as a training school. Accordingly, groups of enlisted men were sent to this plant from time to time during the spring and summer to study details of operation. As a result, when the Government plant was completed, there was at hand an efficient and trained corps of workmen. The plant was ready for operation August 1, 1918, but since the chlorine could not at that time be utilized, operation was not actually begun until September 1st. The cell gas generated by the plant

Training
of
Operating
Force

**Operation
of Plant
Begun**

averaged over 98% chlorine, results which can be achieved only through the combination of efficient construction and skilful operation. This was of sufficient purity to enable its direct use in the manufacture of phosgene without going to the trouble of first liquefying it.

47. Coincident with the building of the chlorine plant, the work of constructing a power house and equipping it with the necessary machinery for furnishing electric power was under way. The site chosen for the power house was on the banks of the Bush River and a short distance from the docks; hence the name "Bush River Power Plant". This plant was to consist of 2 - 10,000 K.W. Allis-Chalmers turbo-generators with Stirling boilers. It was proposed to utilize the electrical power of this plant not only to supplement that obtained from outside sources for generating chlorine in the Government plant under construction, but also to provide power for increasing the output beyond 200,000 pounds per day, since it was almost certain that a greatly increased amount would be demanded if the war continued during any extended period. The engineering plans for the plant were prepared by Sargent & Lundy, and the work of construction was carried out by the Foundation Company. The building consists of steel framework on concrete foundations. It has hollow tile walls and asbestos covered corrugated iron roof. Work was

**Bush River
Power House**



The Bush River Power House. Equipped with 2 - 10000 K. W.
Allis-Chalmers turbo-generators, with Stirling Boilers.

nearly completed when stopped by the signing of the Armistice.

More
Bromine
Required

48. While the program for increasing the chlorine supply was being carried out, steps were also being taken to increase the bromine output of the country. This liquid has a limited use in gas warfare in the production of lachrymators such as xylyl bromide and brombenzylcyanide. The entire bromine output of the country in the pre-war period amounted to less than 1,500,000 pounds annually. This bromine was used almost entirely in the manufacture of bromides, which in turn were used for medicinal and photographic purposes. It was certain that the demand for bromine for these purposes would be increased rather than decreased during the War. It was necessary, therefore, to increase the production to an amount corresponding with the quantity required for toxic gas purposes.

49. The source of bromine is the brine obtained by sinking deep wells in certain localities of the country. The richest bromine bearing brine is that obtained near Midland, Michigan, and the Dow Chemical Company of Midland produces more than two-thirds of the total bromine output of the country. Because of the extensive experience of the Dow Chemical Company in all matters pertaining to the production of bromine, arrangements were made with the Company to superintend the sinking of 17 Government brine wells

Government
Brine
Wells

in the vicinity of Midland. The arrangements provided that the brine secured from these wells be pumped to the plant of the Dow Chemical Company, and bromine there recovered. The work of sinking the wells began in March, 1918, and the entire project was practically completed when the Armistice was signed. The finished plant, known as the "Midland Plant", comprises 16 producing wells, 21 well sites, approximately 25 miles of pipe line, 15 miles of power transmission line, and a 300-K.W. central power plant and pumping station. The plant is now the property of the United States, is in excellent condition, and capable of producing approximately 650,000 pounds of bromine per year.

Mustard
Gas
First used

50. It was during the summer of 1917 that the Germans began to use dichlorethyl sulphide, commonly known in war parlance as "Mustard Gas". But little attention was paid to it at first by the Allies, who regarded it as much less efficacious than the other gases then generally employed. As time passed, however, the Germans used the gas in ever increasing quantities, and more information was gained in regard to its effects upon the troops. It was then realized that for certain purposes this gas was really the most insidious one so far employed. England and France thereupon immediately began to concentrate their efforts in developing a commercial method for its manufacture. The

Methods
of
Preparation

Bureau of Mines, likewise, began to study the problems involved and soon concentrated its energies on this subject. Two general methods for its preparation were known. These were designated by the name of the raw material used in the preparation, as (a) the chlorhydrin method, and (b) the sulphur monochloride method. The former of these methods was apparently the much more expensive of the two, and was very wasteful of chlorine, a serious defect because of the shortage in the chlorine supply. The sulphur monochloride method, on the other hand, seemed to have great advantage in that the chloride could easily be prepared and its conversion into mustard gas brought about in a single operation by the action of ethylene under proper conditions. These conditions, however, had not been worked out satisfactorily.

Contract
for
Mustard
Gas

51. It was known that the Commercial Research Company of Flushing, Long Island, had patented a process for the manufacture of chlorhydrin, and conversion of this into mustard gas was not a difficult matter. In order to avoid delay therefore, and upon the recommendation of the Bureau of Mines, a contract was made with the Commercial Research Company, on April 13, 1918, to build and operate a plant having a capacity of 10,000 pounds daily of Mustard gas. Before work on this plant had proceeded very far, it became increasingly evident from the results at hand

that the sulphur monochloride method was much simpler than the chlorhydrin. Accordingly, on June 28, 1918, there being no prospect of early production by the Commercial Research Company, the contract with this Company was cancelled, and effort was concentrated on the sulphur monochloride process.

52. The sulphur monochloride process on paper looked like a very simple matter. Apparently, it was only necessary to pass ethylene into the sulphur monochloride contained in a vessel (reactor) of suitable size and fitted with appropriate devices for thoroughly mixing the two materials. As a matter of fact, the problem proved to be the most difficult of all those undertaken by Edgewood Arsenal. Heat is evolved in the reaction and must be controlled with the greatest care; otherwise the entire mass rapidly decomposes, resulting in a condition exceedingly dangerous and difficult to handle. The most serious troubles, however, were those resulting from the separation of sulphur which clogged the machinery and pipes. In order to find methods for overcoming these difficulties, the Bureau of Mines had established experimental units not only at the American University, where the Bureau had erected a large laboratory for gas investigation, but also at the plants of the Dow Chemical Company, Midland, Michigan, and Zinsser & Company, Hastings-on-Hudson, New York. An experimental unit was also installed at the Government plant started

Develop-
ment of
Process
for Manu-
facture of
Mustard
Gas

Types of
Reactors
Used

by the Ordnance Department in Cleveland, Ohio, which plant later became the Development Division of the Chemical Warfare Service. In these different plants the following types of reactors were employed:

(a) The American University Type.

This consists of a lead-lined iron tank (2'x4'x5') provided with cooling coils. Thorough dissemination of ethylene through the sulphur monochloride is secured by introducing the gas through a series of filter blocks at the bottom of the converter. These blocks are made of a porous material and the ethylene passing through forms a large volume of small bubbles which rise continuously through the liquid. This type of reactor has a capacity of about 2,000 pounds.

(b) The Dow Type.

This consists of a large cylindrical lead-lined iron drum rotating on its horizontal axis. The gas is disseminated through the liquid by the rotation of the drum. The lower part of the rotating drum is immersed in a tank of water, and in this way the temperature of the reaction is controlled. Cold water may also be sprayed on the tank from above.

Decision
Reached
to Build
Large-
Scale
Plant

53. The experimental work continued night and day, and by May 1, 1918, it was felt that sufficient information was at hand to justify the construction of a large-scale plant at Edgewood. It was recognized that this plant would be experimental at first, and would have to be changed from time to time in accordance with the results obtained. It was believed that in the development of the plant, along with

the experience gained, a large amount of mustard gas would be prepared, and this proved to be the case. As a matter of fact, the preparation of the plans, the construction of the plant and its operation later went hand in hand.

54. About this time reports came from the American Expeditionary Forces to the effect that the French had developed a type of reactor which was reported to be working satisfactorily. The French reactor has a capacity of from 1200 to 1500 pounds. It is water-jacketed and provided with cooling coils. Dissemination of the reacting products is secured by leading in ethylene at the bottom of the still under 50 pounds' pressure. The gas is conducted through a small upright tube in such a way as to draw a current of sulphur monochloride along with it to a point just above the surface of the liquid in the reactor, where it strikes a baffle plate and is thrown down again into the body of the liquid. A little later the Cleveland laboratory developed a modification of the French type, which became known as the Cleveland type of reactor. This has about the same capacity as the French type, namely, from 1200 to 1500 pounds. It is not water-jacketed, however, and the ethylene is run in from the top of the reactor in place of the bottom as in the French type. It is provided with suitable cooling coils, and dissemination of the reacting materials is secured by means of a

French
Type of
Reactor

stirrer fitted with lead covered paddles.

**Plant to
be Built
in Units**

55. After due consideration of the various types of reactors that had been devised, it was decided to use the French type at the proposed plant. The plans called for a plant of a daily capacity of 100,000 pounds, built in four units radiating from a central ethylene compressor system. Each unit was designed to contain 16 reactors. The main buildings of the plant were to consist of steel framework with corrugated iron sides; some of the smaller buildings were to be of hollow tile construction. Construction on the plant began May 18, 1918.

**Ethylene
Production**

56. For generating the ethylene it was decided to use the method developed at the Cleveland laboratory. This consists in passing the vapor of alcohol, mixed with about 25% of its weight of steam, through a vertical iron tube (9" x 8') filled with kaolin heated to about 500° C. The resulting ethylene is washed with water and dried with sulphuric acid.

57. Coincident with the building of the plant, steps were being taken to secure adequate supplies of raw materials necessary for the production of mustard gas, namely alcohol and sulphur monochloride. The alcohol was required for the generation of ethylene and could be obtained in the quantities desired on the open market. The normal output of sulphur monochloride, on the other hand, is very

**Procurement
of Alcohol
and Sulphur
Monochloride**

small so that but little of it was available. It is easily made, however, by passing chlorine into a large tank partially filled with sulphur. Co-operation of the chlorine producers of the country was desired and representatives of the various plants met in Baltimore on May 27, 1918. As a result of the conference, contracts were entered into which made it possible to secure approximately 300,000 pounds of sulphur monochloride per day, in case this amount was demanded. Production of this amount, however, would necessitate a corresponding decrease in the output of bleach, large quantities of which were being utilized by the Government in the manufacture of chlorpicrin. There was no objection to this, however, because it was felt that mustard gas would almost entirely replace chlorpicrin. In order to guard against any deficiency of sulphur monochloride, it was also decided to install a Government plant at Edgewood, (page 51).

**Procurement
of
Sulphur**

58. In accordance with the terms of the sulphur monochloride contracts, the Government was to supply the necessary sulphur. This had to be shipped from Louisiana and Texas, and the difficulties of transportation during the winter of 1917-18 were well known. In order to guard against a possible shortage during the winter months of 1918-19, large quantities of sulphur were shipped during the summer and fall and stored at the



Mustard Gas Plant at Eigewood, in process of construction. Photograph taken on June 17, 1918. (Compare with photograph on the following page taken on July 23, 1918).



Mustard Gas Plant at Edgewood nearing completion.
Photograph taken on July 23, 1918.

various sulphur monochloride plants.

Development
of Large-
Scale
Mustard Gas
Plant

59. Before the first large unit of the mustard gas plant was ready for operation, it was decided to replace 4 of the 16 French reactors composing this unit with those of the Cleveland type. The American University reactor also seemed to be giving good results, and two of these were designed for use and erected at one side of the main plant. These were the first to come into production, starting June 19, 1918. Trouble soon arose due to plugging of the pores of the filtros blocks, and some other method had to be devised for introducing ethylene. For this purpose there was constructed a nozzle, which was placed near the bottom of the reactor and arranged in such a way that the ethylene, forced downward through the nozzle, carried along with it a current of sulphur monochloride, thus insuring a thorough dissemination of the gas throughout the liquid. The Cleveland type of reactor gave excellent results at first, but soon failed because the lead covering on the paddles was torn off, thus exposing iron to the action of the chemicals.

Operation
of Plant
Begun

60. Operation in the first large unit began August 1, 1918. The French nozzles for introducing ethylene did not work well, and were immediately replaced by those of the Edgewood design. The separation of sulphur in the reactors and pipe was a source of constant trouble, but was partially eliminated by running each charge as soon as com-

plete into large settling tanks. Here the sulphur separated and the resulting clear liquid removed by compressed air.

Larger
Type of
Reactor
Decided
Upon

61. Before the construction of the second large unit began, much additional information was at hand, and it was decided to replace the smaller type of reactors (capacity about 1500 pounds) by a much larger type having a capacity of about 30,000 pounds. The unit was to consist of 7 of these. The reactors were of the jacketed type and in addition were provided with extensive cooling coils through which refrigerated brine could be circulated so as to keep the temperature down. It was proposed to disseminate the ethylene through the ^{liquid} gas by introducing it either through filtros blocks or by nozzles of the Edgewood design. In addition, stirrers were provided principally for keeping the contents of the reactor uniform in temperature. Careful consideration was also given to methods for removing the sulphur formed in the reaction.

The
Levinstein
Process
England

62. About the middle of August, Brigadier-General Amos A. Fries of the American Expeditionary Forces sent to the United States Major Frederick Pope with the plans of the so-called "Levinstein Process", which had been tried out on an experimental scale in England and was reported to have an advantage in that the reaction could be controlled more readily and the sulphur, in place of separating and

clogging the equipment, remained in colloidal suspension in the finished product. The Levinstein Process differed from those used in the United States in the following particulars:

- (a) The reaction is carried out at a temperature of 35° C. rather than 55° C.
- (b) The reactors are made of cast iron and are not lead lined.
- (c) In place of introducing into the reactor the entire charge of sulphur monochloride at the beginning of the operation, this liquid is led in gradually along with the ethylene.

**Levinstein
Reactor
Installed**

63. Immediately upon Major Pope's arrival (August 17th), it was decided to install a trial reactor of the Levinstein type, and the work was pushed as rapidly as possible. While this work was being carried out, a number of the reactors in the first unit of the large plant were kept in operation, producing on an average of 20,000 pounds mustard gas daily. The Levinstein reactor was ready for operation October 3, 1918. It had a capacity of 24,000 pounds, and operated in a fairly satisfactory manner. During the latter part of October, the first large reactor in the second unit was completed, and the work of installing the remaining reactors was nearing completion. The operation of the others had practically ceased, however, because every available mustard gas container was filled with the material, and this was the condition when the Armistice

**Producing
Capacity
of Mustard
Gas Plant**

was signed. At this time the plant had a producing capacity of 60,000 pounds per day, and a rapid increase up to 200,000 pounds per day was confidently expected. The total production of mustard gas at Edgewood was 1,422,000 pounds. Of this amount approximately 380,000 pounds had been shipped overseas in bulk, and 600,000 pounds had been loaded into shell. The remainder was held in storage at Edgewood at the date of the Armistice, awaiting supplies of shell and boosters.

64. Because of the large amount of mustard gas required to meet the War program and in order to guard against delays due to accidents, it was decided to construct more than one plant for the production of this material. The National Aniline & Chemical Company of Buffalo, New York, offered to assist the Government without profit to itself in the development and operation of a large-scale plant. This Company was known to have a large and efficient research laboratory, and it was thought that the experience gained by the Company in the development of the dye industry of the country would be of great value in overcoming the difficulties attending the manufacture of mustard gas. Moreover, the raw materials for the manufacture of the gas were available at Buffalo on short hauls, while the finished product could be shipped to Edgewood on the same special train with the phosgene manufactured at

Buffalo
Mustard
Gas Plant

Niagara Falls. A contract was made, therefore, with the Company to supervise the construction and operation of a plant with a capacity of 100,000 pounds daily. The contract was dated July 6, 1918. Construction on the plant began July 17th and was about 90% complete when the Armistice was signed. The plant was known as the "Buffalo Plant of Edgewood Arsenal".

65. Attention has already been called to the fact (page 41) that the Bureau of Mines had operated an experimental unit for the manufacture of mustard gas at the plant of Zinsser & Company, Hastings-on-Hudson. The work had been extensive in character, and it was thought that the experience gained by those connected with this experimental unit would be of value in the construction and operation of a large-scale plant. Moreover, the firm of Zinsser & Company offered to lease to the Government, at the nominal sum of \$1.00 per year, a tract of land adjacent to the plant of the Company, upon which a large-scale plant could be built. The land bordered on the Hudson River, thus making it possible to ship the finished product directly from the plant to our armies in France. It was decided to lease the land and build a third large-scale plant for the manufacture of mustard gas. Construction began July 8, 1918. As originally proposed, the capacity was to be 50,000 pounds daily, but this was later extended to a capacity of 100,000 pounds. At the date of the Armistice a 20,000 pound unit was finished, the remainder of the plant being

Hastings
Mustard
Gas Plant



571

NOV. 9 1918

Edgewood Arsenal Hastings Plant

Shurtz & Brothers photo N.Y.

General View of the Hastings Plant of Edgewood Arsenal located at Hastings-on-Hudson, N. Y. Capacity from 25 to 50 tons of mustard gas daily.

about 95% complete. This plant is known officially as the "Hastings Plant of Edgewood Arsenal".

Work Handi-
capped by
Epidemic

66. The work at Edgewood Arsenal was seriously handicapped during the late summer and early fall by the epidemic which prevailed throughout the country. The disease was especially severe at Edgewood, and the work at a number of plants was practically suspended while the epidemic was at its height. Notwithstanding the severity of the disease, many of the afflicted men kept doggedly at their work, realizing its great importance and value in winning the War.

Government
Sulphur
Monochloride
Plant

67. It was stated on page 45 that a decision was reached to build a sulphur monochloride plant at Edgewood in order to guard against any deficiency in this material. The operation of such a plant in connection with the chlorine plant at Edgewood would make it possible also to utilize the tail gases from the chlorine liquefying plant, and thus effect considerable saving. The work on the plant began June 20, 1918, and operation on September 1st, the first chlorine generated in the Government chlorine plant being utilized in the manufacture of sulphur monochloride. The plant as constructed consists essentially of 30 tanks (78" diameter and 35' long), each capable of producing 20,000 pounds of sulphur monochloride per day. It was the intention, however, to use only a limited number of the tanks

for actual production, the remainder being used for storage. The process of manufacture is as follows: The tanks are partially filled with sulphur, and chlorine passed in. The reaction proceeds rapidly with the evolution of sufficient heat to keep the sulphur in a molton condition. If the chlorine is passed in too rapidly, the heat generated may be sufficient to boil off the sulphur monochloride formed; hence water pipes are provided so that, if necessary, a supply of cold water may be sprayed upon the tanks and the temperature thus kept within the proper limits.

68. Civilian labor was employed in the construction work of the Arsenal. Before the chemical plants were completed, however, it became evident that such labor could not be used in their operation. Not only was this labor difficult to secure, but the wages were abnormally high, and as a whole, the work was inefficient. Moreover, it was found that such civilian laborers as were available could not be depended upon to work in the chemical plants because of the danger, both real and imaginary, attending the manufacture of such highly toxic material. It was decided, therefore, to utilize enlisted men in this work, and as the projects advanced increased numbers of such men were detailed to the Arsenal.

Character
of labor
Employed

Number of
Men at
Edgewood

69. The following table gives the number of officers, enlisted men and civilians engaged in work at Edgewood at the dates designated. Exact data concerning the number of enlisted men and officers present during January, February and March, 1918, is not available.

DATE	OFFICERS	ENLISTED MEN	CIVILIANS
January 1, 1918			3661
February 1.			5249
March 1.			5970
March 25.	68	441	
April 8.	70	781	5446
May 1.	84	1308	6248
June 1.	88	1424	8483
July 1.	112	1624	8542
August 1.	121	3439	6622
September 1.	180	6360	4587
October.	233	6948	3066
November.	290	6971	1884
December 1.	314	7161	
December 27.	280	4222	615

70. In June 1918, the enlisted men were formed into four battalions, each battalion being composed of a sufficient number of men to carry out the duties assigned. The strength of the battalions and the duties assigned to each are as follows:

Military
Organiza-
tion

(a) 1st Battalion:

Strength on November 11, 1918. 21 officers
1218 enlisted men

Duties	* * * * *	All duties connected with cost accounting work, checking, time, keeping; guarding the plant.
--------	-----------	--



FORWARD MARCH

The Edgewood plants were all operated by commissioned and enlisted personnel. These were formed into battalions and companies and drilled daily.

(b) 2nd Battalion:

Strength on November 11th - 75 officers
3393 enlisted men

Duties * * * * * Operation of the filling plant and the maintenance of the entire Arsenal.

(c) 3rd Battalion:

Strength on November 11th - 100 officers
1570 enlisted men

Duties * * * * * Operation of the chemical plant.

(d) 4th Battalion:

Strength of November 11th - 26 officers
513 enlisted men

Duties * * * * * Operation of the chlorine plant.

Each battalion was further subdivided into companies of approximately 250 men each with proper officers.

71. On November 11, 1918, there were 272 military police and 191 guardsmen on guard duty.

72. When the work first began at Edgewood, temporary barracks were erected for the workmen. They were of the standard cantonment type of construction, being wooden buildings covered outside with tar paper and lined inside with composition board. The buildings were heated with the standard cantonment stoves and lighted with electricity. The number of these barracks was increased from time to time as the number of workmen grew, until finally there were

Construct-
ion of
Barracks

accommodations for 6,000 men. These temporary barracks were afterwards used by enlisted men. In addition to the temporary barracks, permanent ones were provided accomodating about 2,500 men. These had hollow tile walls, plastered both inside and out with cement plaster. Each one contained a general assembly room, shower bath, was steam heated and lighted with electricity. Taken altogether, 86 cantonments were built accomodating about 8,500 men. Three officers' quarters were built with accomodations for 290. One of these was of the temporary type of construction, one of the permanent, and the third of an intermediate type.

Diversion
for
Men

73. It was known that the work at Edgewood would be severe and dangerous as well; consequently, provisions were made for ample diversion for the men when off duty. Both the Y.M.C.A. and K. of C. constructed huts which were provided with ample library facilities and moving picture outfits. A band was organized and athletics encouraged. Teams were formed and gave a good account of themselves in a number of contests.

Production
of chlor-
picrin at
Edgewood
Plant

74. The work of construction of the chlorpicrin and phosgene plants at Edgewood continued uninterruptedly during the spring months of 1918. On June 5th the chlorpicrin plant was ready for operation, the first run being made actually on June 9th. The maximum amount of product made in this plant in any one day of 24 hours was on Sep-



"All Work And No Play Makes Jack A Dull Boy".

Production
of Chlor-
picrin at
Stamford
Plant

tember 25th, when 61,200 pounds were produced. The total output of the plant up to the date of the signing of the Armistice was 2,326,000 pounds.

75. Reference has been made (pages 11-12) to the contract let to the American Synthetic Color Company for the production of chlorpicrin. It was found necessary, in order to obtain maximum production, for the Government to take over this plant. Accordingly, it was leased and operated by the Government until closed at the signing of the Armistice. There was produced at this plant (known as the Stamford Plant) a total of 3,226,000 pounds. The total production of chlorpicrin at the Edgewood and Stamford Plants was 5,552,000 pounds, of which amount 3,806,000 pounds were shipped overseas in bulk. The total producing capacity of the two plants at the date of the Armistice was 3,000,000 pounds monthly.

Production
of Phosgene
at
Government
Plants

76. Production in the phosgene plant at Edgewood began July 5, 1918, and gradually increased until the date of the Armistice, when it had reached 40,000 pounds per day. The second building, increasing the daily capacity to 80,000 pounds, was expected to be completed by November 15th, and the third building, giving a total capacity of 120,000 pounds per day, by March 1, 1919. The total production of phosgene at Edgewood was 1,870,000 pounds. The Niagara Falls Plant, constructed and operated under the guidance of the Oldbury

Electro-Chemical Company (page 9), came into production on August 5, 1918. The total amount produced at this plant was 870,000 pounds. There was also produced at the experimental plant located at Niagara Falls a total of 83,070 pounds. In addition to the above, the Bound Brook Plant pages (21-22) produced 410,000 pounds. The total amount of phosgene produced for war purposes was 3,233,070 pounds; of this amount 840,000 pounds were shipped overseas in bulk. The total production figures for phosgene and chlorpicrin, arranged in tabular form, are as follows:

PLANT	PHOSGENE	CHLORPICRIN
Edgewood Plant	1,870,000 pounds	2,326,000 pounds
Niagara Falls Plant	870,000 "	
Niagara Falls Experimental Plant	83,070 "	
Bound Brook Plant	410,000 "	
Stamford Plant		<u>3,226,000</u> "
TOTAL	3,233,070 "	5,552,000 "

77. When the plants for the large-scale production of toxic gases came into operation, an embarrassing situation arose because of the lack of shell and boosters. The nature of these gases is such as to make it impossible to store up any large quantities, to say nothing of the danger attending such a procedure. For a while a considerable amount of material was shipped overseas in bulk, and there loaded into shell or otherwise utilized. The total amount of different gases shipped in bulk is as follows:

Overseas
Shipment
of Toxic
Gases in
Bulk

Liquid Chlorine	2,976,000 pounds
Chlorpicrin	3,806,000 "
Phosgene	840,000 "
Mustard Gas	380,000 "
White Phosphorus	342,000 "
Tin Tetrachloride	212,000 "

Later the shipment of these gases in bulk was ordered stopped, and from that time all production was correspondingly limited by the supply of shell and boosters, a condition which prevailed up to the time of the signing of the Armistice.

Filling
Plants
#2 and #3

78. Construction on Filling Plant #2 was begun in April 1918. Like Filling Plant #1, it was to be made up of four wings, each of which was to be provided with the necessary equipment for filling 6" or 8" shell. Its capacity was rated at 36,000 shell per day. The entire plant was about 80% complete at the date of the Armistice; a part of it, however, had been equipped temporarily and used for filling 75 mm. shell with mustard gas. Construction on Filling Plant #3 began early in June 1918. This was designed with two wings, each of which was to be provided with equipment for filling 75 mm. shell at the rate of 42,000 per day. The plant was about 80% complete when work was stopped on November 11, 1918. The filling plants had cement floors, steel framework and tile walls.

79. In addition to Filling Plants #1, #2, and #3, the following filling plants were constructed or nearing completion at the time of the Armistice:

Filling
Plants for
Grenades,
Smoke Shell
& Drop Bombs

(a) STANNIC CHLORIDE GRENADE PLANT - capacity 25,000 per day. A total of 363,776 grenades was filled.

(b) WHITE PHOSPHORUS GRENADE PLANT - Capacity 30,000 per day. This was not completed at the time of the Armistice. The necessary equipment, however, had been received, housed in a temporary building and operated, a total of 440,153 grenades being filled.

(c) WHITE PHOSPHORUS SMOKE SHELL PLANT - capacity as follows:

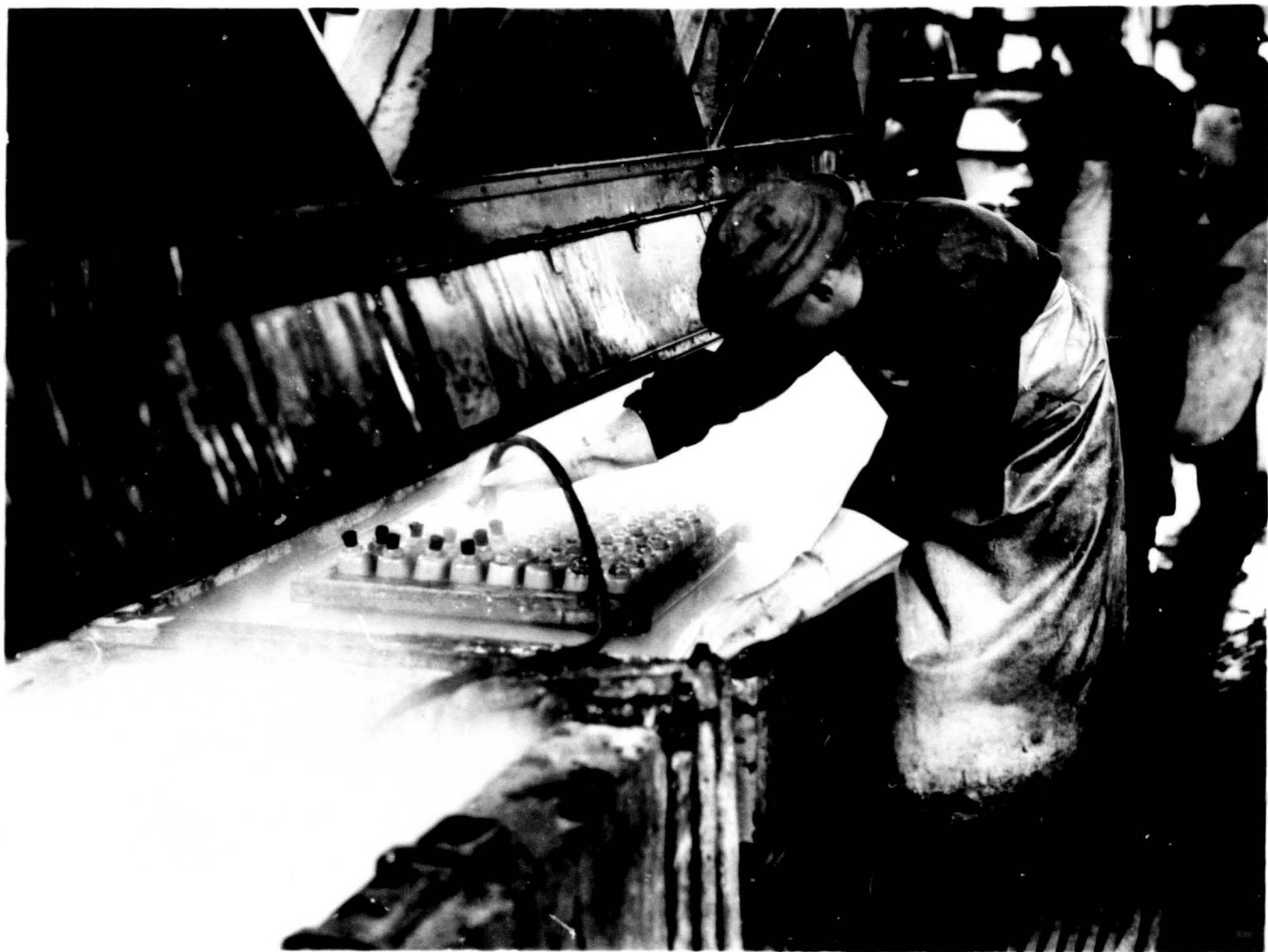
155 mm. shell - capacity -	2,000	per day, or
4.7" or 5" shell - "	4,000	" " "
75 mm. shell - "	6,000	" "

This plant was completed but not operated because of lack of appropriate shell.

(d) INCENDIARY DROP BOMB PLANT - capacity 2,000 per day. This was completed and operated, a total of 2,646 bombs being filled.

Incendiary
Drop Bomb
Plant

80. It will be noted from the statement made in the previous paragraph that only a small number of incendiary drop bombs were filled. The war program called for a large number of these, and Edgewood Arsenal had been notified early in the year of 1918 to prepare to fill them. Accordingly, a suitable plant was erected and machinery installed. The bombs were of two types, designated as Mark I and Mark II. When the bombs began to arrive, it was found immediately that the Mark I variety could not be loaded with the joint in the bomb as then made. By the time this was corrected, orders were received not to fill any more of this type as they were found to be unsuitable for overseas use. About 2,000 of the Mark II type were loaded when orders were re-



Filling hand grenades with phosphorus.

ceived to stop the work as it was found that the bomb did not function properly when dropped under service conditions. The equipment devised by the Arsenal for filling these bombs was found to work admirably and had a minimum capacity of 2,000 bombs per day.

Filling
of
Livens
Drums

81. The demand for Livens drums by the American Expeditionary Forces was very insistent, and arrangements were made to fill these as soon as the production of the drums began. It was decided to utilize the entire production of the phosgene plant at Niagara Falls for filling Livens. Operation of this plant in the filling of these began on August 25, 1918, and kept pace with the receipt of the drums, a total of 18,768 being filled up to the time of the Armistice. An annex to Filling Plant #1 at Edgewood was also constructed for filling these drums and the work of filling began on August 30th. Up to the time of the Armistice there had been received and filled at Edgewood 6,921 Livens drums.

Filling
Plant
First
Operated

82. It has already been stated (page 29) that a portion of Filling Plant #1 was sufficiently completed early in March 1918 to admit of limited operation, had the necessary shell and boosters been at hand. It was not until July 11, 1918, that a sufficient supply of these was at hand to warrant the starting of the plant. The first shell filled was of the 75 mm. type, and the filling material was a

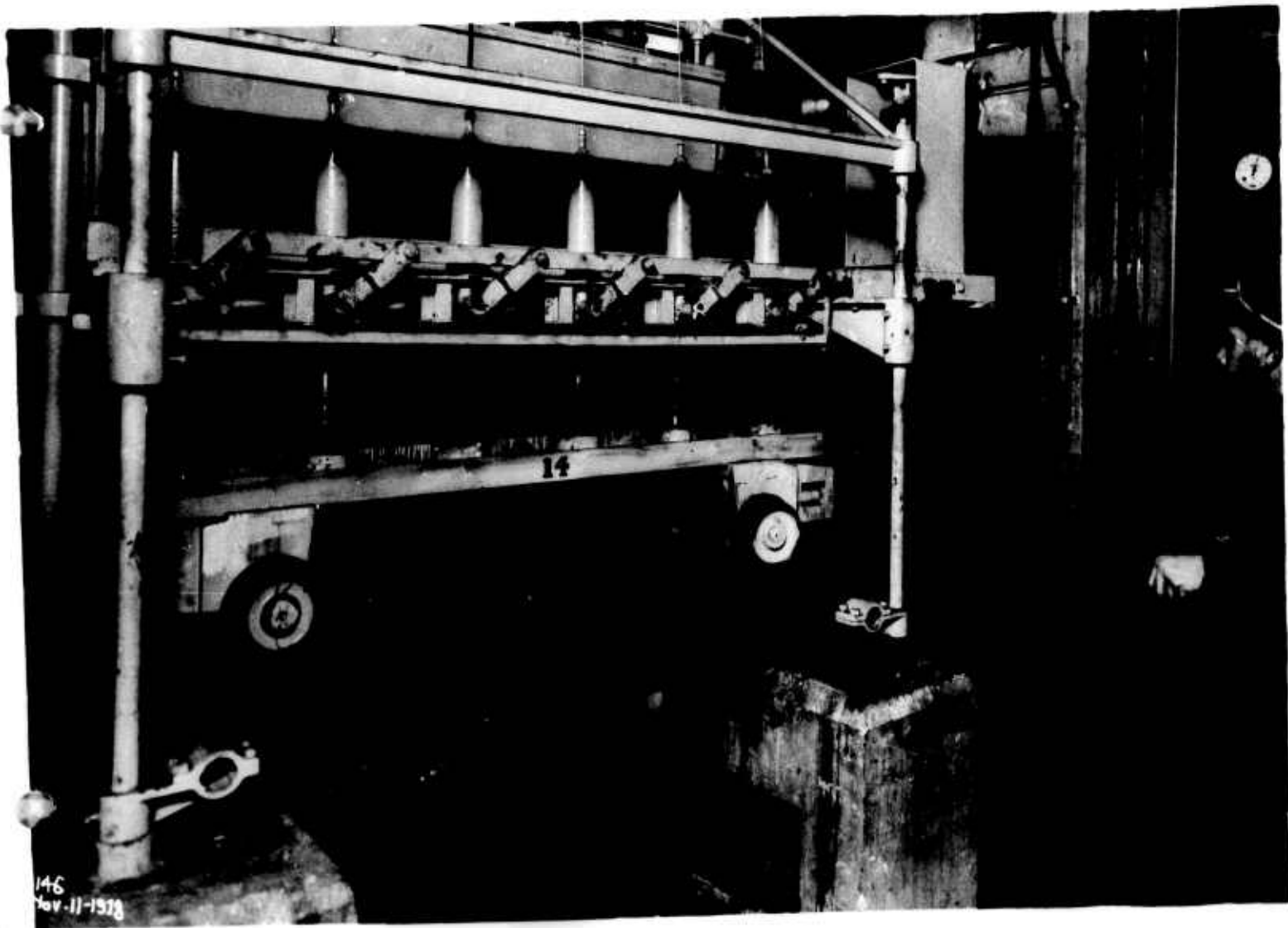
mixture of chlorpicrin and stannic chloride (commonly known as N.C.). Shell filling with mustard gas began on September 13, 1918.

Construct-
ion Turned
over to
Construct-
ion Divis-
ion

83. The construction work carried on at Edgewood during the winter of 1917-18 was under the direct supervision of the Arsenal itself. On April 1, 1918, by order of the Commanding officer, all construction, with the exception of that of the filling plant, the equipment of which was highly technical in character, was turned over to the Construction Division. This Division proved to be of the greatest service in the development of Edgewood. Under its guidance the work of construction was systemized and pushed promptly to completion. Due regard was always given to economy, there being selected in each case a type of building the construction of which was as inexpensive as possible in order to serve the general object in view. Some idea can be gained of the extent of the construction at Edgewood from the fact that when the Armistice was signed there had been erected on the Arsenal grounds 558 buildings. In addition there had also been built 14.83 miles of improved roadways, 21 miles of standard gauge, 8 miles of 21½" narrow gauge, and 7 miles of 36" narrow gauge railway. Two different water supply systems had also been installed.

Extent
of Con-
struction

84. One of the first projects carried out on the grounds of the Arsenal was the installation of a water



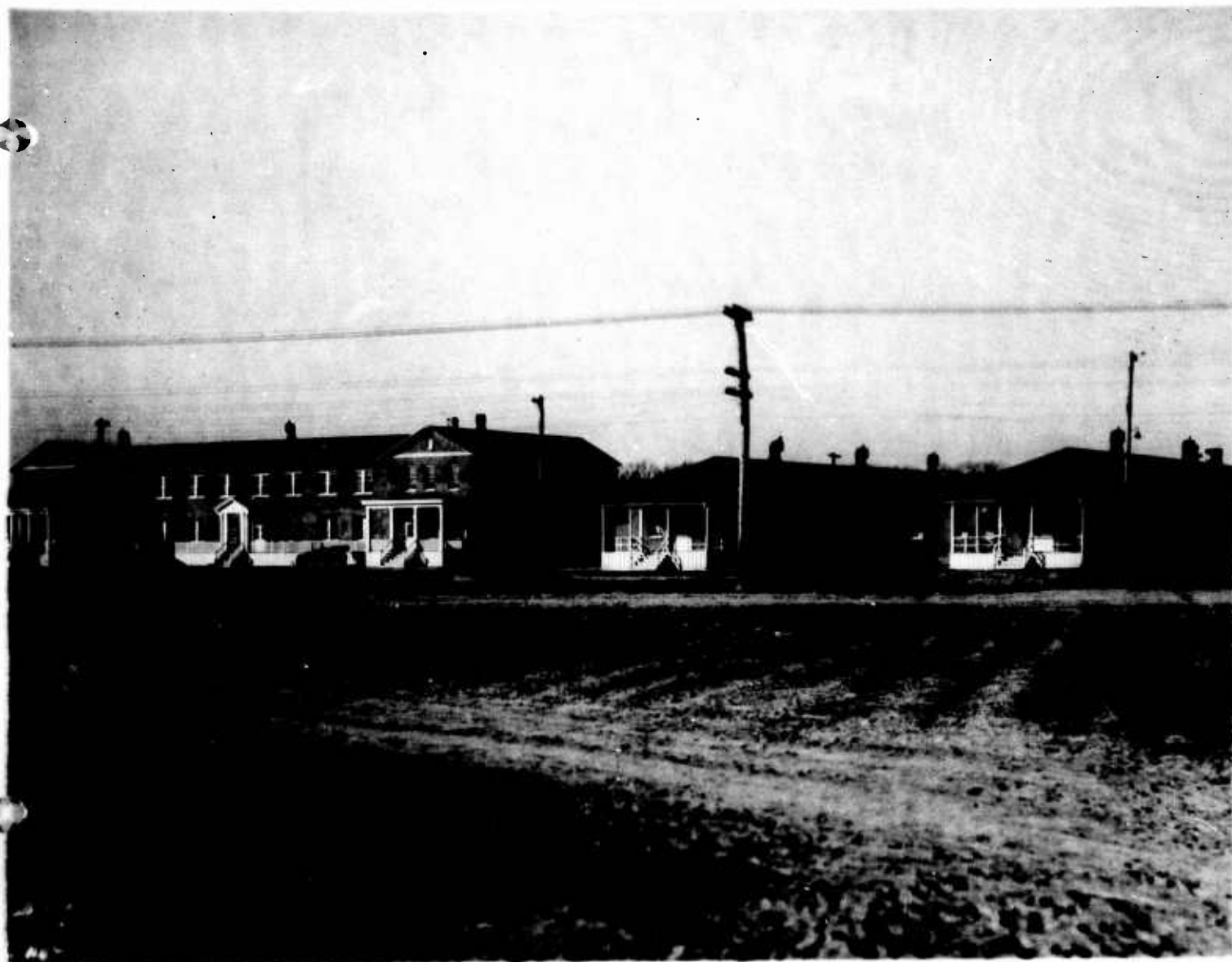
Filling 75 mm. shell with mustard gas.

Water
Supply
Systems

system, bringing water from Bush River, nearby, for the operation of the filling plants (page 26). The system furnished salt water, which was satisfactory for the purpose indicated. Fresh water, however, would have to be provided for sanitary and certain industrial purposes. A number of artesian wells were sunk and some water obtained from this source, but the supply was entirely inadequate to meet the demands. The Surgeon General's Office co-operated in the selection of a suitable source for a larger supply. It was finally decided to pump water from Winter's Run, a distance of about 4 miles from Edgewood. A dam was constructed for storing the water and a suitable purification system installed. A temporary equipment made it possible to utilize this source of supply from May 16, 1918; the permanent equipment was completed and first operated on September 15, 1918. The plant has a capacity of 2,000,000 gallons per day.

Hospital
Facilities

85. Inasmuch as the work of the Arsenal centered around toxic gases, it was evident that many casualties would result, and steps were taken, therefore, to provide suitable hospital facilities. It was decided to build 3 camp hospitals, to be located near the field of operation where accidents were most likely to occur, and one base hospital. The plans for the latter were drawn under the general direction of the Surgeon General's Office and the construction was carried out by the Construction Division. The work was



The Base Hospital at Edgewood consists of 34 buildings and has accommodations for 314 patients under normal conditions. As many as 1300 however were taken care of during the epidemic which prevailed throughout the country in the Fall of 1918. The Hospital is permanent in construction and complete in every respect. The photograph shows the administration building and two of the ward buildings.

begun on the buildings in April 1918, and they were ready for occupancy early in September. The completed unit consists of 34 buildings with accommodations for 314 men under normal conditions, or 420 men if emergency demands the increase. The construction is permanent in character and consists of 12" hollow tile walls plastered both inside and out with cement plaster. The buildings are steam heated and electrically lighted. A separate sewage disposal system was installed. The hospital is complete in every respect.

Shell
Dumps

86. There were also constructed during the summer 3 buildings known as "shell-dumps", having a total floor space of 2.3 acres and designed for receiving and testing the empty shell and boosters, as well as for testing, painting and boxing the filled shell. In addition, a fireproof general storage building, with floor capacity of nearly 2 acres, was built.

Storage
Magazines

87. It was the original intention of the War Department to store loaded shell in the Government warehouses at Curtis Bay, Maryland. Later, it was found impossible to do this. It became necessary, therefore, to build storage magazines at Edgewood, and accordingly, 12 of these were constructed with a total floor capacity of approximately 5½ acres. The buildings are fireproof, consisting of steel framework with tile walls.

Manufac-
ture of
Bromben-
zylcyanide
Authorized

88. In addition to the projects already mentioned, Edgewood Arsenal was instructed to build a plant for the production of brombenzylcyanide, which is one of the most powerful lachrymators known. This compound is prepared from toluol. The toluol is first converted into benzyl chloride through the action of chlorine in the presence of a suitable catalyzer, sunlight or a brilliant artificial light being the most effective for this purpose. By treatment with sodium cyanide, the benzyl chloride is next converted into benzyl cyanide and this product, on treatment with bromine vapor forms the final product desired, namely, brombenzylcyanide. The operations must all be carried out in glass or lead-lined iron stills. The details of the method of manufacture were developed by the Bureau of Mines at the American University Experiment Station.

89. A great deal of attention was given to the selection of a suitable location for the proposed large-scale plant. Naturally, there was much to be said in favor of building it at Edgewood in connection with other plants located there. It was felt, however, that it was unwise to locate too many plants at any one place, since danger always attended their operation, and the segregation of too many at one place would increase this danger to an unjustifiable degree. A number of other localities were considered, among them Kingsport, Tennessee, in connection with the plant of the Federal

Location
of Plant
Selected
and Plant
Construct-
ed

Dyestuff & Chemical Company. It was known that this plant was not being utilized efficiently, and some criticism had been offered to the effect that the Government had not availed itself of the advantages offered there. There would be needed in the manufacture of brombenzylcyanide a certain amount of chlorine, steam, water and electric power, all of which the Federal Dyestuff & Chemical Company were willing to furnish on an equitable basis. Moreover, the manager of the Company assured Edgewood Arsenal that if the plant were located in that locality the Company would facilitate the erection and operation of the same. Accordingly, a tract of land adjacent to the plant of the Federal Dyestuff & Chemical Company was leased and the government plant was built on this ground. It is only fair to add here that subsequent experience proved that the choice of this location was unwise. The construction began on July 8, 1918, and operation on October 29th. The plant, which was designated as the "Kingsport plant of Edgewood Arsenal", was just completed to the point where it could operate at its maximum capacity of 6,000 pounds per day when the Armistice was signed. The total production of the cyanide at the plant was a trifle over 10,000 pounds.

90. On August 23, 1918, Edgewood Arsenal was instructed to proceed with the plans for a plant designed to manufacture 20,000 pounds daily of diphenylchlorarsine. This product is especially valuable since it readily passes through

Production
of
Diphenyl-
chlorar-
sine

the ordinary gas mask and produces violent sneezing. This necessitates the removal of the masks and thus subjects the troops to the effects of the poisonous gases used along with the arsenical compound. The compound is prepared by the reaction between chlorbenzol, arsenious chloride and metallic sodium. The operation is exceedingly difficult and dangerous inasmuch as some of the intermediate products are spontaneously combustible and explosive as well. For this reason a location for the plant had to be selected remote from all other buildings. Croyland, Pennsylvania, was finally selected as a suitable site, since it was in a sparsely settled district and yet had good railroad facilities with plenty of coal and natural gas available. Construction on the plant began October 18, 1918, and was only about 5% complete when work was stopped by the signing of the Armistice. The plans called for the construction of a plant with a capacity of 20,000 pounds per day, and it was expected to be in operation by April 1, 1919.

Production
of
D. M.

91. On September 19, 1918, instructions were received by Edgewood Arsenal to make arrangements for manufacturing the arsenical compound known as D.M. Accordingly, on September 23, 1918, negotiations were begun with the Newport Chemical Works, Carrollville, Wisconsin, looking toward the manufacture of 20,000 pounds D.M. per day by this Company. On October 2nd. laboratory investigations and plant design

work were begun by this Company, and the work was in progress at the date of the Armistice. It was expected that the production of D.M. would reach the desired figure of 20,000 pounds per day by February 1, 1919.

92. Of all the materials used directly in filling shell only three could be obtained in the amounts desired from already existing chemical firms. These are as follow:

Procurement
of Phospho-
rus, Tin
Tetrachlor-
ide and
Titanium
Tetrachlor-
ide

(a) Phosphorus.

The supply of white phosphorus required for filling smoke shell was purchased from two companies, namely, Oldbury Electro-Chemical Company, Niagara Falls, New York, and Electric Reduction Company, Buckingham, Quebec, Canada. The total supply obtained from these two sources was 2,012,000 pounds.

(b) Tin Tetrachloride.

The supply of this material required for filling hand grenades and for mixing with chlorpicrin to form the so-called N.C. mixture was obtained from the following firms:

Metal & Thermit Corporation, New York City.
Vulcan Detinning Company, Sewaren, N. J.

A small amount was also obtained from the Republic Chemical Company, Pittsburg, Pennsylvania. The total amount obtained from these 3 sources was 1,390,000 pounds.

(c) Titanium Tetrachloride.

This is used as a substitute for phosphorus in filling smoke shell. The entire supply, amounting to 362,000 pounds, was furnished by the Niagara Smelting Corporation, Niagara Falls, New York.

Casualties
at the
Edgewood
Plant

93. Because of the highly toxic character of the materials manufactured and filled into shell in the different plants of Edgewood Arsenal, every precaution was taken in the construction of these plants as well as in their operation to avoid accidents from this source. Of course, a certain number of such accidents was bound to occur, and provisions had been made for their proper treatment (page 62). A list of the casualties at the Edgewood plants, together with the agent causing each, is given in the following table:

TOXIC AGENT	:June:	July:	Aug.:	Sept.:	Oct.:	Nov.:	Dec.:	Total
Mustard Gas	14	41	190	153	227	47	2	674
Stannic Chloride		3	8	15	21	3		50
Phosgene			3	7	22	17	1	50
Chlorpicrin		14	18	9	3			44
Bleach Chlorine		2	39	2	1			44
Liquid Chlorine		1	3	2	7	5		18
Sulphur Chloride			2	1	6			9
Phosphorus		2	7	5	1			15
Caustic Soda			3		3	4		10
Sulphuric Acid			4	3	1			8
Picric Acid			2					2
Carbon Monoxide					1			1
TOTALS	14	63	279	197	293	76	3	925

The term "casualty" as used in making out the foregoing table is defined as a new case of gas injury requiring medical attention at either the field or base hospitals. Considering the magnitude and danger of the work, and the large number of men employed, the number of casualties is relatively small. But

three fatalities at the Edgewood Plant were traceable to toxic gas poison, two of these being due to phosgene and one to mustard gas.

**Casualties
at the
Outside
Plants**

94. The number of casualties at the outside plants of Edgewood Arsenal was relatively small; the exact data is not available. There was but one fatality at the outside plants - and this was due to phosgene.

95. For the shipment of toxic gases and of materials used in their manufacture, a large number of containers was required. These were constructed with a view of guarding against the dangers that would result from leaky containers, and all had to stand the tests fixed by the Bureau of Explosives. The containers used fall under the following heads:

**Containers
for
Shipment
of Gases**

- (a) ONE-TON CONTAINERS, so-called because each will hold one ton of liquid chlorine. These were made to withstand a hydrostatic pressure of 500 pounds per square inch.

Number purchased - 9,000. Number delivered - 7,000.

- (b) 300-POUND PHOSGENE Cylinders, designed by the Engineering Bureau and made to withstand a 500-pound hydrostatic pressure, also a 250-pound air test.

Number purchased - 3,500. Number Delivered - 2,500.

- (c) 55-GALLON STEEL DRUMS - standard acid drums. They are subjected to 30 pounds air pressure.

Number purchased 76,000. Number Delivered - 25,942.

- (d) 75-POUND CHLORINE CYLINDER - standard pattern.

Number purchased and delivered 2,000

- (e) CHLORINE TANK CARS, made especially for the shipment of liquid chlorine. Each tank has a capacity of 30,000 pounds and was subjected to a pressure test of 500 pounds.

Number purchased and delivered 20

- (f) SULPHUR CHLORIDE TANK CARS, originally designed for the shipment of chlorpicrin, but later used in the shipment of sulphur monochloride. Each tank was subjected to a hydrostatic pressure test of 60 pounds.

Number purchased and delivered 17

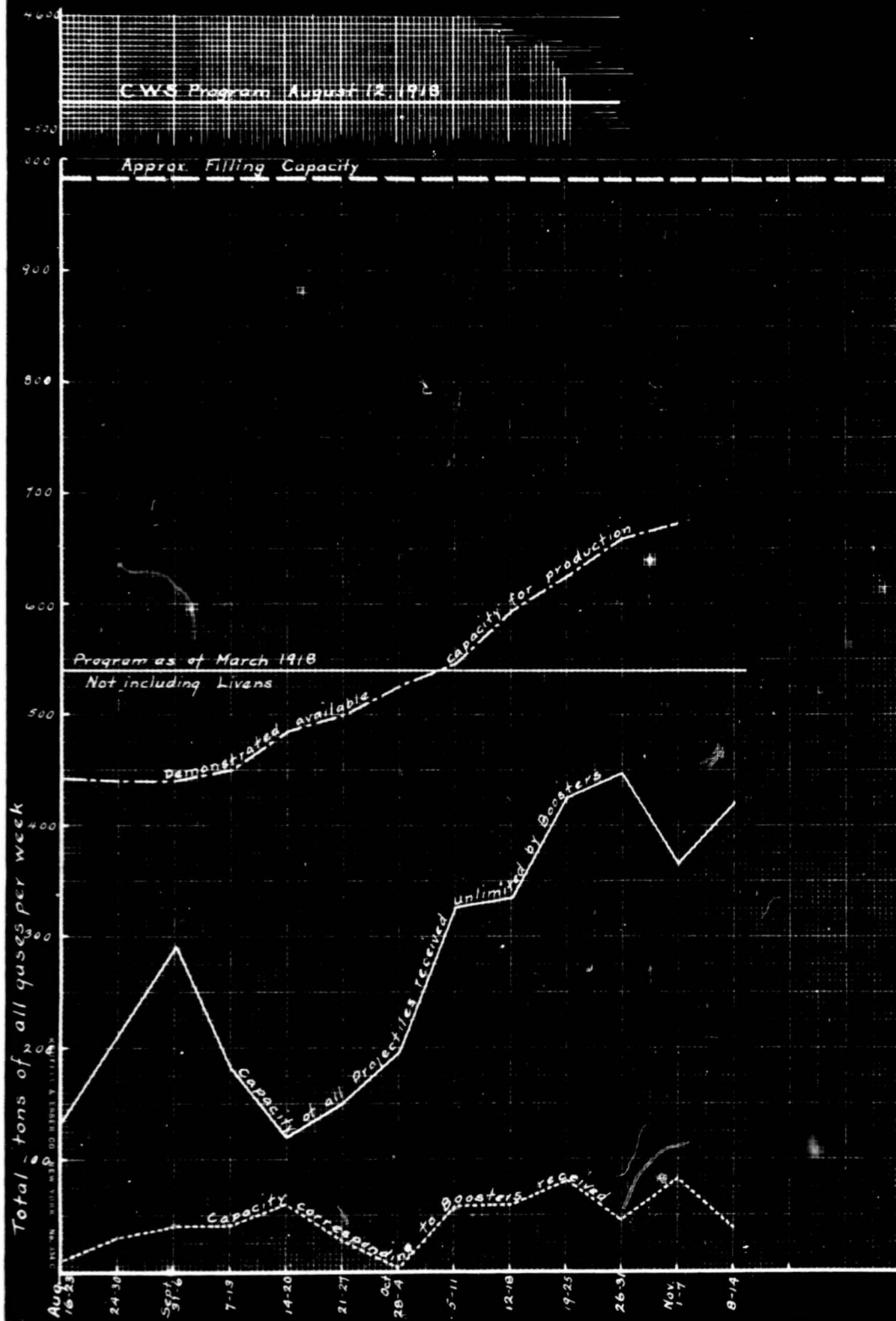
96. The chart on page 72 gives in graphic form certain detailed information concerning toxic gas, as well as the delivery of gas shell and boosters at Edgewood. Reference to this chart brings out the following facts:

Production
of Toxic
Gas Limited
by the
Supply of
Shell and
Boosters

- (a) That the gas program as of March, 1918, called for approximately 545 tons toxic gas weekly.
- (b) That the Chemical Warfare Service program of August 12, 1918, called for a much larger amount, viz: about 4,525 tons per week.
- (c) That the approximate filling capacity of the Edgewood Arsenal Plants from August to November, 1918, was nearly 1,000 tons per week.
- (d) That the toxic gas production during this same period increased from 450 to 675 tons per week.
- (e) That the capacity of all projectiles received, unlimited by boosters, varied during the same period from 125 to 450 tons per week.
- (f) That the maximum capacity corresponding to boosters received was less than 100 tons per week.

It will be noted, therefore, that even if the necessary number

of boosters had been available, the number of gas shell delivered was far less than the number required to accommodate the gas production. The shell, however, were of no value without the corresponding boosters, so that the limiting factor became really that of the supply of boosters. This supply was sufficient to take care of only a relatively small fraction of the toxic gas production.



TOTAL PRODUCTION OF TOXIC MATERIAL.

The amounts of toxic materials produced by the Arsenal during the year 1918, are given in the table on page 74, expressed in pounds per month. The table also records the amount of each gas shipped overseas in bulk. There is also appended the total monthly producing capacity of the Arsenal for each gas on November 1, 1918, as well as the estimated capacity on January 1, 1919.

TOTAL NUMBER OF SHELL AND OTHER CONTAINERS FILLED

The number of shell and other containers filled with toxic materials is given in the table on page 76. There is, likewise, given the total monthly capacity of the filling plants on the date of the Armistice, as well as a statement of the number of filled shell shipped overseas.

The shell are designated by the number representing the diameter of the shell. The approximate amount of toxic gas required for filling each type of shell (10.5% void) is as follows:

SHELL	PHOSGENE	N. C.	MUSTARD GAS
75 mm.	1.32 pounds	1.75 pounds	1.35 pounds
4.7"	4.27 "	6.20 "	4.20 "
155 mm.	11.00 "	15.40 "	10.35 "
8"	22.00 "	30.30 "	21.60 "
Livens Drums	30.00 "		

Each gas grenade held 0.446 pounds of stannic chloride; the smoke grenade 0.67 pounds of white phosphorus.

It will be noted in the table that the only shell actually filled were those of the 75 mm. variety. The reason for this is that either the shell of other sizes or the accompanying boosters were not available. At all times the capacity of the filling plants and supplies available for filling were in excess of the number of shell, grenades and Livens drums supplied.

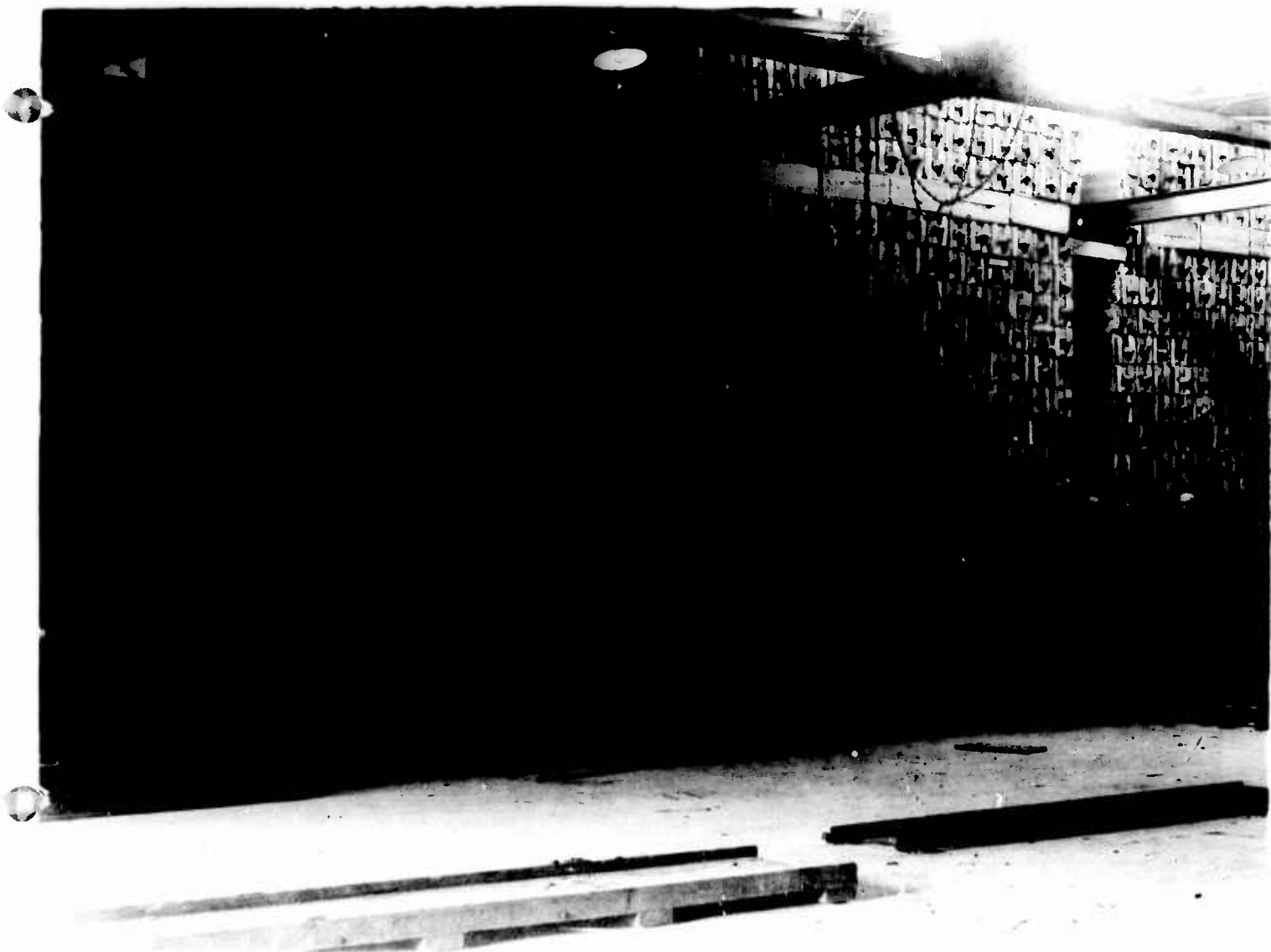
SHELL, GRENADE, LIVENS DRUMS AND DROP BOMBS FILLED.

75 mm. Shell:		Grenades:		Livens Drums:	Incendiary Drop Bombs
Chlorpicrin and Tin Tetra- chloride:	Mustard Phosgene: Oil	White Phos- phorus:	Tin Tetra- chloride:	Phosgene:	Mark 1 Mark 11
1918:					
July	62,866	8,696	1,639	1,738	350
Aug.	125,951	170,160	56,763	6,355	1,998
Sept.	110,358	51,421	127,319	12,026	100
Oct.	109,704	110,928	147,669	5,570	8
Nov.	15,892	98,948	30,386		6
Total:	424,771	440,153	363,776	25,689	542
Total No.) shipped) overseas)	300,000	224,984	175,080	18,600	2,104

Total Monthly Capacity of Filling Plants on Date of Armistice:

75 mm. shell: 4.7" shell:	155mm. shell: 6" shell:	Gas Grenades:	Smoke Grenades:	Livens Drums:
2,400,000	450,000	540,000	180,000	750,000
				480,000
				30,000

(Stokes shell, drop bombs, and other special containers not included)



Twelve storage magazines with a total floor capacity of $5\frac{1}{2}$ acres, were built at Edgewood for the storage of shell. The above view shows the interior of one of these magazines.

PROCUREMENT OF RAW MATERIALS

The chief chemical raw materials used were common salt for chlorine; bleach and picric acid for chlor-pierin; alcohol and sulphur monochloride for mustard gas; and sulphur for the manufacture of sulphur monochloride; and bromine and benzyl chloride for brombenzyleyanide. These were obtained from commercial sources, except that a plant for sulphur monochloride was constructed at Edgewood as a supplement to sources of this material elsewhere. New plant facilities for sulphur monochloride, for bromine, and for benzyl chloride were constructed by commercial interests at the instance of Edgewood Arsenal. The number of pounds of these raw materials procured in each month, with totals, is given in the following table:

PROCUREMENT OF RAW MATERIALS - POUNDS PER MONTH

1918	Common Salt	Bleach	Picric Acid	Alcohol	Sulphur Mono- chloride	Sulphur	Bromine	Benzyl Chloride
March							38,000	
April			100,000				60,000	
May		9,990,000	508,000	64,000			12,000	
June	1,176,000		626,000	392,000	398,000	3,488,000	14,000	
July	5,160,000	8,928,000	476,000	324,000	920,000	1,878,000	32,000	
Aug.	2,574,000	9,034,000	728,000	816,000	1,036,000	8,814,000	64,000	
Sept.	1,306,000	6,536,000	500,000	220,000	824,000	5,522,000	18,000	10,000
Oct.	7,142,000	7,840,000	668,000	1,142,000	1,036,000	5,210,000		16,000
Nov.		56,000	112,000	760,000	1,994,000			
Dec.					416,000			
TOTAL	17,358,000	42,384,000	3,718,000	3,718,000	6,624,000	24,912,000	238,000	26,000

Preparations
for Closing
the Plant

For nearly a month previous to the declaration of the Armistice the various plants at the Arsenal either had shut down entirely or were operated only to an extent sufficient to maintain the machinery and equipment in good working order. This condition was due to the fact that there was no outlet for the material produced at the plants. The delivery of boosters had been so limited that only a relatively small amount of the output of the chemical plants had been utilized and this surplus had accumulated until all available storage space was filled. There was a large supply of hand grenades but the number of these already filled was in excess of the requirements. As soon as the Armistice was signed, work was immediately begun to put the plants in condition for an indefinite shut-down. Machinery was cleaned, painted and oiled, and all out-door equipment properly placed in storage. The work of construction was stopped except in a few instances where it was necessary to finish buildings nearly completed. Steps were also taken to dispose of the large accumulations of toxic gas. It is probable that this will ultimately be sunk in the ocean. At the date of writing, February 1st, about two-thirds of the men who were at the Arsenal at the time of the Armistice have been discharged. The remainder are being employed in guarding the plant, in painting shell, and in unloading and storing the large amount of equipment of various sorts

that is being sent to the Arsenal for storage. By March 1st, it is expected that the work will be completed to such an extent as will make it possible to diminish the number to about 500. This number will be required permanently in order to properly police the grounds, keep the buildings and equipment in good repair, and to take care of shipments of stored materials.

A P P E N D I X

PROPERTIES OF CERTAIN MATERIALS

USED IN

GAS WARFARE

(a) Phosgene:

This is a definite chemical compound and has the composition expressed by the formula COCl_2 . At ordinary temperature it is a colorless gas but condenses to a liquid at 8°C . Its odor has been variously described as suggestive of green corn, of apples, and of musty hay. It is highly toxic in character. When inhaled in any considerable quantity, death soon results; in a small quantity, it produces but little immediate discomfort, but it is necessary, in such cases, to keep the patients absolutely quiet for several days, otherwise they are apt to die from delayed heart action. Phosgene is used in shell; mixed with chlorine it is also used in wave attacks. When a phosgene shell bursts the material soon dissipates. It is used, therefore by troops to shell positions which they hope to shortly occupy.

(b) Chlorpicrin:

When pure, chlorpicrin is a colorless liquid, boiling at approximately 112°C . It is a definite chemical compound and has the composition expressed by the formula CNO_2Cl_3 . While not so poisonous as some of the other products used in warfare, it is, nevertheless, very toxic and has the additional advantage in that it produces nausea and vomiting and is a pronounced lachrymator (tear-producer) as well. Because of its relatively high boiling point it is not readily dissipated, its effects being marked after a considerable interval of time. It is used in shell.

(c) Mustard Gas:

The chemical name of mustard gas is dichlorethylsulphide and it has the composition expressed by the formula $\text{C}_2\text{H}_4\text{Cl}_2\text{S}$. It was first prepared in 1886. When pure, it is a colorless or slightly yellow oily liquid, boiling at from $215^\circ - 217^\circ \text{C}$. at a pressure of 750 mm. It freezes at 14°C . but the product as ordinarily made contains small percentages of impurities and this remains liquid at 0°C . or below. It possesses a faint mustard smell; hence the derivation of the term "mustard gas". Because of its high boiling point it does not decompose dissipated for several days. It has a very corrosive action upon the flesh, producing severe blisters similar to those caused by burns. When breathed, its vapor likewise produces this same effect upon the lung tissues.

(d) Chlorine:

This is an elementary substance. At ordinary temperatures it is a greenish yellow gas of suffocating odor. Through the immediate effects of cold and pressure it is readily condensed to a liquid and is ordinarily shipped in this form, stored in cylinders. When inhaled in any considerable quantity it has a strong, unbearable, suffocating effect and rapidly corrodes the lung tissue. It is used either alone or mixed with phosgene in wave attacks, but is not adapted as a filling material for shell.

(e) Brombenzylcyanide:

This compound has the composition expressed by the formula $C_6H_5CHCNBr$. When pure it freezes at $29^\circ C$. forming white or brownish crystals. As ordinarily prepared, however, it is a brownish oily liquid having a boiling point of $230^\circ C$. It is one of the most powerful lachrymatory substances known, and its use in gas warfare is due to this property.

(f) Diphenylchlorarsine:

This compound is a white crystalline solid, melting at $44^\circ C$. Its composition is expressed by the formula $(C_6H_5)_2ClAs$. As ordinarily prepared it is impure and forms a brown, viscous liquid resembling tar. It is a powerful sternutator (that is, sneeze producer) and causes watering of the eyes. It is very effective since it readily passes through the gas masks when in a finely divided state, and causes sneezing. This necessitates removal of the masks, subjecting the troops to the effects of poisonous gases used along with the arsenical compound.

(g) 3-Phenylimino-6-Chlorarsino--Cyclohexadiene-1,4.

This compound is commonly known as D.V. It has the composition expressed by the formula $C_6H_5N=C_6H_4=AsCl$ and resembles diphenylchlorarsine in all of its properties.

(h) White Phosphorus:

This, like chlorine, is an elementary substance. When pure, it is a colorless, translucent, waxy solid which melts at $44.1^\circ C$. It is very inflammable and when burning forms an intensely voluminous white cloud which is effective in gas warfare for masking the troops.

(i) Tin Tetrachloride:

This is a colorless liquid boiling at 114.1°C . It has the composition expressed by the formula SnCl_4 . When exposed to the air it fumes strongly and readily passes through the gas masks. It is used in hand grenades and is very effective especially in driving out troops from dug-outs.

(j) Titanium Tetrachloride:

This resembles tin tetrachloride in its properties. It has the composition expressed by the formula TiCl_4 . When exposed to air it produces white clouds similar to, but not so voluminous, as those produced by the combustion of phosphorus. It is used in hand grenades as a substitute for phosphorus in producing smoke

LIST OF EDGEWOOD ARSENAL PLANTS FOR THE MANUFACTURE
OF
TOXIC GASES

- (a) Edgewood Arsenal, Edgewood (Maryland) Plant.
Project - Manufacture of chlorpicrin. Operated by
Edgewood Arsenal.
- (b) Edgewood Arsenal, Edgewood Plant.
Project - Manufacture of phosgene. Operated by
Edgewood Arsenal.
- (c) Edgewood Arsenal, Edgewood Plant.
Project - Manufacture of mustard gas. Operated by
Edgewood Arsenal.
- (d) Edgewood Arsenal, Edgewood Plant.
Project - Manufacture of chlorine. Operated
by Edgewood Arsenal.
- (e) Edgewood Arsenal, Edgewood Plant.
Project - Manufacture of sulphur monochloride. Operated
by Edgewood Arsenal.
- (f) Edgewood Arsenal, Stamford (Connecticut) Plant.
Project - Manufacture of chlorpicrin. Operated
by Edgewood Arsenal.
- (g) Edgewood Arsenal, Niagara Falls (New York) Plant.
Project - Manufacture of phosgene. Operated
under the supervision of the Oldbury
Electro-Chemical Company.
- (h) Edgewood Arsenal, Midland (Michigan) Plant.
Project - Sinking of seventeen brine wells for
the purpose of securing adequate
supplies of bromine. Operated under
the supervision of the Dow Chemical Co.
- (i) Edgewood Arsenal, Bound Brook (New Jersey) Plant.
Project - Manufacture of phosgene. Operated
under the supervision of Frank Hemingway, Inc.

- (j) Edgewood Arsenal, Hastings (Hastings-on-Hudson, N.Y.) Plant.
Project - Manufacture of mustard gas. Operated
by Edgewood Arsenal.
- (k) Edgewood Arsenal, Buffalo (New York) Plant.
Project - Manufacture of mustard gas. Operated
under the supervision of National Aniline &
Chemical Company.
- (l) Edgewood Arsenal, Kingsport (Tennessee) Plant.
Project - Manufacture of brombenzylcyanide. Operated
by Edgewood Arsenal.
- (m) Edgewood Arsenal, Croyland (Pennsylvania) Plant.
Project- Manufacture of diphenylchlorarsine. Operated
by Edgewood Arsenal.

C O N F I D E N T I A L

Order)
No. 54)

WAR DEPARTMENT
Washington,

March 6, 1918.

Extract

• • • • • • • • • •

PAR 42. The appointment (promotion) of Lieutenant Colonel William H. Walker, Chemical Service Section, National Army, to the grade of Colonel, Ordnance Department, National Army, with rank from March 1, 1918, is announced. He will proceed to Baltimore, Maryland, and take station at that place as Commanding Officer of the Gunpowder Neck Reservation, reporting his arrival by letter to the Chief of Ordnance.

 The travel directed is necessary in the military service.

• • • • • • • • • •

By order of the Secretary of War:

PEYTON C. MARCH,

Major General, Acting Chief of Staff.

Official:

H. P. McCAIN,
The Adjutant General

ISSUED AT WASHINGTON

WAR DEPARTMENT

Office of the Chief of Ordnance
Engineering Bureau
451 Pennsylvania Ave
Washington

April 2, 1918.

FROM: General Administration Bureau,
Office of the Chief of Ordnance.

TO: William H. Walker, Ord. Dept., N.A.

SUBJECT: Establishment of Gunpowder Reservation.

1. You will assume command of the Gunpowder Reservation which forms that part of the Aberdeen Proving Ground established by proclamation of the President, date of October 22, 1917, which is bounded on the north by the Pennsylvania railroad, on the east by the Bush River, on the West by the Gunpowder River, and on the south by a line drawn as indicated on the enclosed map. For the purpose of better prosecuting the construction program hereinafter outlined, you are authorized to establish your headquarters in the City of Baltimore.

2. The commissioned and enlisted personnel heretofore assigned to the Gunpowder Reservation project will be transferred from the Trench Warfare Section of the Engineering Bureau to your command. The transfer of such Civil Service employees as may be desired will be effected by mutual agreement between yourself and the Chief of the Trench Warfare Section of the Engineering Bureau.

3. You shall administer the Gunpowder Reservation in conformity with the rules and regulations governing the administrations of arsenals.

4. The sum of \$19,040,000 has been set aside on the books of this office for the construction and initial operation of filling plants, chemical plants, chlorine plants and additional power installation, as well as the necessary cantonments, hospital, storehouses, etc., and a gas shell proving ground with laboratory and animal farm. Since the Procurement Division of this office has already been obligated for disbursements for certain portions of the construction program,

the exact part of the above amount to be later allotted for your use will be decided upon after determination of the monies to be expended from this office.

5. You will submit, for the approval of the Acting Chief of Ordnance at the earliest practicable date, a specific program covering construction work and operation, requesting an additional allotment of funds, if necessary. You will negotiate for all construction or equipment not already contracted for, or under negotiation by the Procurement Division, and you will be charged with the prosecution of the entire construction and operation program.

6. The operation of all plants of the Gunpowder Reservation shall be carried out by commissioned and enlisted personnel in so far as practicable. You will call upon this office for the necessary enlisted personnel guards and operatives. You will initiate steps towards the commissioning of such commissioned personnel as may be required to fill the quota which will be allotted you.

7. Reports covering all tests pertaining to gas warfare will be submitted to the Engineering Bureau.

8. In addition to the installation of the Gunpowder Reservation, you will assume charge of the following outside Government-owned plants manufacturing chemicals for use in the operation of the plants on the Gunpowder Reservation, viz:

- (a) Plant located at the Oldbury Chemical Co., at Niagara Falls, N. Y.
- (b) Plant located at the Frank Hemingway Co., Inc., Bound Brook, N.J.
- (c) Plant located at the American Synthetic Color Co., Stamford, Conn.
- (d) The sinking of seventeen (17) Brine Wells, about three miles from the Plant of the Dow Chemical Co., Midland, Mich.

Chemical Plant No. 4, located at Saltville, Va., is being erected under the Bureau of Mines, and when placed in operation will be under your charge.

C.B. WHEELER,
Brig. Gen., Ordnance, N.A.
Acting Chief of Ordnance.

General Orders,)
No. 62.)

WAR DEPARTMENT
Washington, June 28, 1918.

I--1. Under authority conferred by sections 1, 2, 8, and 9 of the act of Congress "Authorizing the President to increase temporarily the military establishment of the United States," approved May 18, 1917, and the act "Authorizing the President to coordinate or consolidate executive bureaus, agencies, and offices, and for other purposes, in the interest of economy and the more efficient concentration of the Government", approved May 28, 1918, in pursuance of which act the President has issued an executive order dated June 25, 1918, placing the Experiment Station at American University under control of the War Department, the President directs that the Gas Service of the Army be organized into a Chemical Warfare Service, National Army, to include:

- a. The Chemical Service Section, National Army.
- b. All officers and enlisted men of the Ordnance Department and Sanitary Corps of the Medical Department as hereinafter more specifically specified (regular officers affected being detailed and not transferred).

2. The officers for this service will be obtained as provided by the third paragraph of section 1 and by section 9 of the act of May 18, 1917, the enlisted strength being raised and maintained by voluntary enlistment or draft.

3. The rank, pay, and allowance of the enlisted men of the Chemical Warfare Service National Army, shall be the same as now authorized for the corresponding grades in the Corps of Engineers.

4. The head of the Chemical Warfare Service, National Army, shall be known as the Director of the Chemical Warfare Service, and, under the direction of the Secretary of War, as such, he shall be, and hereby is charged with the duty of operating and maintaining or supervising the operation and maintenance of all plants engaged in the investigation, manufacture, or production of toxic gases, gas-defense appliances, the filling of gas shell, and proving grounds utilized in connection therewith and the necessary research connected with gas warfare, and he shall exercise full, complete, and exclusive jurisdiction and control over the manufacture and production of toxic gases, gas defense appliances, including gas-shell filling plants and proving grounds utilized in connection therewith, and all investigation and research work in

(G.O. 62).

connection with gas warfare, and to that end he shall forthwith assume control and jurisdiction over all pending Government projects having to do or connected with such manufacture, production, and operation of plants and proving grounds for the Army and heretofore conducted by the Medical Department and Ordnance Department under the jurisdiction of the Surgeon General and the Chief of Ordnance, respectively, and all material on hand for such investigation or research, manufacture or production, operation of the plants and proving grounds, and all lands, buildings, factories, warehouses, machinery, tools and appliances, and other property, real, personal, or mixed, heretofore used in, or in connection with, the operation and maintenance of such plants and proving grounds for the purpose of investigation or research, manufacture or production, already procured and now held for such use by, or under the jurisdiction and control of the Medical Department or the Ordnance Department, all books, records, files, and office equipment used by the Medical Department or the Ordnance Department in connection with such investigation or research, manufacture or production, or operation of plants and proving grounds, all rights under contract made by the Medical Department or Ordnance Department in, or in connection with, the operation of such plants and institutions as specified herein, all rights under contract made by the Medical Department or Ordnance Department in, or in connection with, such work, and the entire personnel (commissioned, enlisted, and civilian) of the Ordnance Department and Sanitary Corps of the Medical Department as at present assigned to or engaged upon work in, or in connection with, such investigation of research, manufacture or production, or operation of plants and proving grounds, are hereby transferred from the jurisdiction of the Ordnance Department and the Medical Department and placed under the jurisdiction of the Director of the Chemical Warfare Service, it being the intention hereof to transfer from the jurisdiction of the Medical Department and the Ordnance Department to the jurisdiction of the Director of the Chemical Warfare service, every function, power, and duty connected with the investigation, manufacture, or production of toxic gases, gas-defense appliances, including the necessary research connected with gas warfare, gas-shell filling plants, and proving grounds utilized in connection therewith, all property of every sort or nature used or procured for use in, or in connection with, said operation of such plants and proving grounds and the entire personnel of the Ordnance Department and Sanitary Corps of the Medical Department as at present assigned to, or engaged upon work in, or in connection with, the operation and maintenance of such plants engaged in the investigation, manufacture, or production of toxic gases, gas defense appliances, including gas-filling plants and proving grounds utilized in connection therewith.

(G.O. 62).

5. All unexpended funds of appropriation heretofore made for the Medical Department or Ordnance Department and already allotted for use in connection with the operation and maintenance of plants now engaged in, or under construction for the purpose of engaging in, the investigation, manufacture, or production of toxic gases or gas defense appliances, including gas shell filling plants, are hereby transferred to, and placed under the jurisdiction of, the Director of the Chemical Warfare Service for the purpose of meeting the obligations and expenditures authorized herein; and, in so far as such funds have not been already specifically allotted by the Medical Department and the Ordnance Department for the purposes specified herein, they shall now be allotted by the Secretary of War, in such proportions as shall to him seem best intended to meet the requirements of the situation and the intention of Congress when making said appropriations, and the funds so allotted by the Secretary of War to meet the activities of the Chemical Warfare Service, as heretofore defined herein, are hereby transferred to, and placed under the jurisdiction of, the Director of the Chemical Warfare Service for the purpose of meeting the authorized obligations and expenditures of the Chemical Warfare Service.

6. This order shall be and remain in full force and effect during the continuation of the present war and for six months after the termination thereof by proclamation of the treaty of peace, or until therefore amended, modified, or rescinded.

II-- By direction of the President, Maj. Gen. William L. Sibert, United States Army, is relieved from duty as Director of Gas Service, and is detailed as Director of the Chemical Warfare Service, National Army.

(322.06, A.G.O.)

By order of the Secretary of War:

PEYTON C. MARCH,
General, Chief of Staff.

Official;

H. P. MCCAIN,
The Adjutant General.

EDGEWOOD ARSENAL

BALTIMORE, MD.

May 4, 1918.

General Order
No. 7

1. In accordance with Office Order No. 207, Office of Chief of Ordnance, under date of April 30, 1918, the gas manufacturing plants at Stamford, Connecticut; Bound Brook, New Jersey; Niagara Falls, New York; Charleston, West Virginia; Midland, Michigan; the gas manufacturing and shell filling plants at Edgewood, Maryland; the Lakehurst Experimental Grounds, Lakehurst, New Jersey; and the Cleveland Laboratory, Cleveland, Ohio, which were formerly known as Gunpowder Reservation, will in the future be designated **EDGEWOOD ARSENAL**.

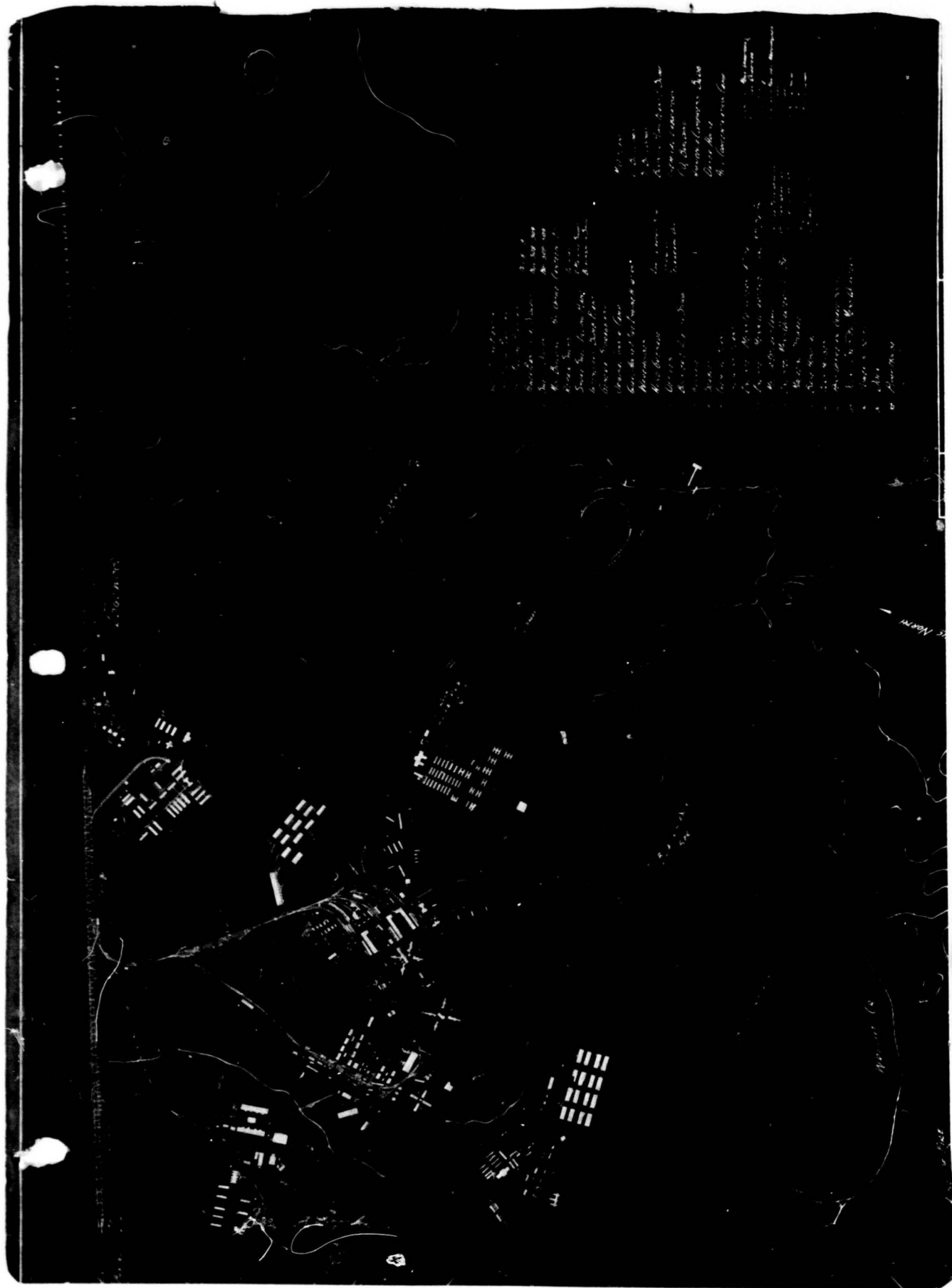
2. In order to distinguish the various activities making up Edgewood Arsenal the gas manufacturing and shell filling plants on Gunpowder Neck will be known as **Edgewood Plant, Edgewood Arsenal**, that at Stamford, Connecticut, as the **Stamford Plant, Edgewood Arsenal**; that at Bound Brook, New Jersey, as **Bound Brook Plant, Edgewood Arsenal**, that at Niagara Falls, New York, as the **Niagara Falls Plant, Edgewood Arsenal**; that at Charleston, West Virginia, as the **Charleston Plant, Edgewood Arsenal**; and that at Midland, Michigan, as the **Midland Plant, Edgewood Arsenal**. The experimental grounds at Lakehurst, New Jersey, will be designated **Lakehurst Experimental Grounds, Edgewood Arsenal**, and the Laboratory at Cleveland, Ohio, will be designated **Cleveland Laboratory, Edgewood Arsenal**.

3. The General Offices of Edgewood Arsenal are located at 311 W. Monument St., Baltimore, Md.

4. All officers will be governed accordingly.

By order of COLONEL WALKER:

C. E. PARTRIDGE,
Major, Ordnance, U.S.A.



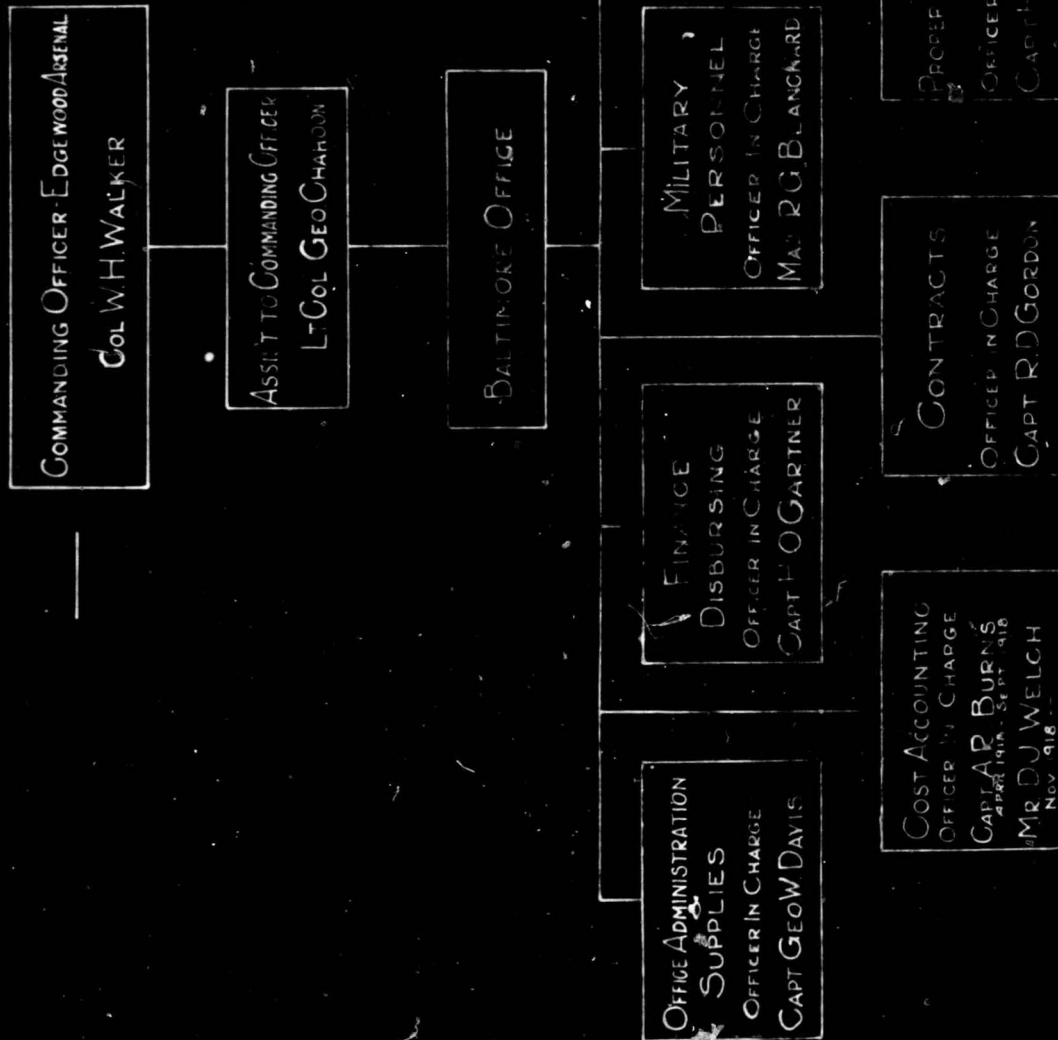
EDGEWOOD ARSENAL
OFFICER IN CHARGE
COL. V. H. WALYD

ASSIST. COMM. OFFICER
LT. COL. GEO. CHAHOON

BALTIMORE OFFICE
OFFICER IN CHARGE
LT. COL. GEO. CHAHOON

EDGEWOOD PLANT
EXECUTIVE OFFICER
LT. COL. W. G. GALLOWAY
AUG. 10, 1918 — JAN. 8, 1919
LT. COL. E. B. ELLICOTT
JAN. 8, 1919

OUTSIDE PLANTS
OFFICER IN CHARGE
LT. COL. W. M. McDONALD



ORGANIZATION CHART

EDGEWOOD ARSENAL
COMMANDING OFFICER

- COL W H WALKER

ASST COMMANDING OFFICER

LT COL GEO CHAFFOON

EXECUTIVE OFFICER

AT EDGEWOOD

LT COL W G GALLOWAY

ALSO CHIEF OF THE

LT COL E B ELLICOTT

MILITARY ADMINISTRATION

- OFFICER IN CHARGE

MAJ F J WAGNER

CONSTRUCTION

- OFFICER IN CHARGE

LT COL E B ELLICOTT

- FILLING PLANTS

OFFICER IN CHARGE

LT COL E M CHANCE

AUG 1ST 1918 - OCT 15 1918

MAJ F W MACK

OCT 15 1918

CHEMICAL PLANTS

OFFICER IN CHARGE

MAJ GEO F FELKER

MAY 4 1918 - JULY 1 1918

MAJ D J DEMOREST

JULY 23 1918

CHLORINE &

CAUSTIC SODA

OFFICER IN CHARGE

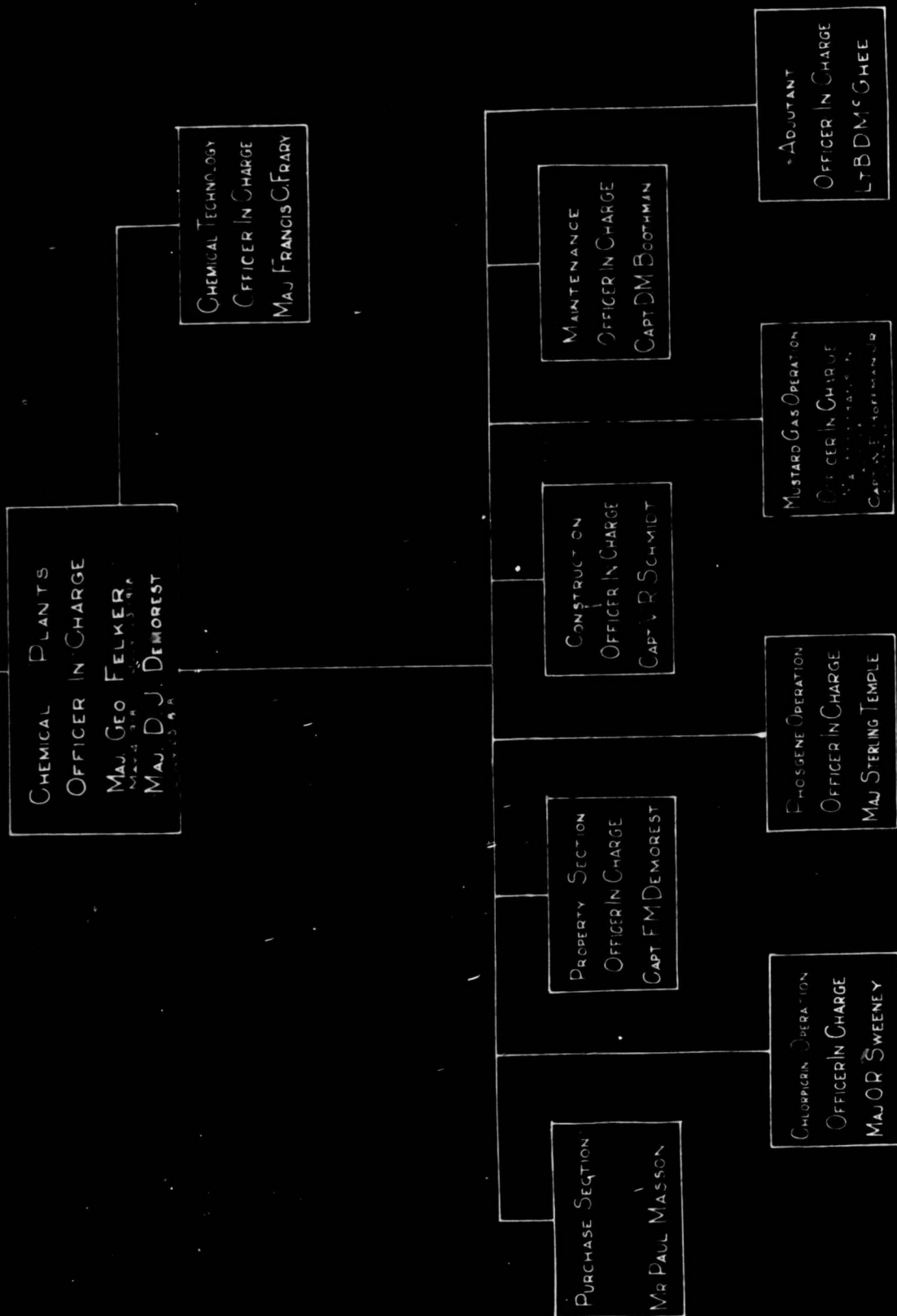
LT COL C F VAUGHN

CHEMICAL LABORATORY

- OFFICER IN CHARGE

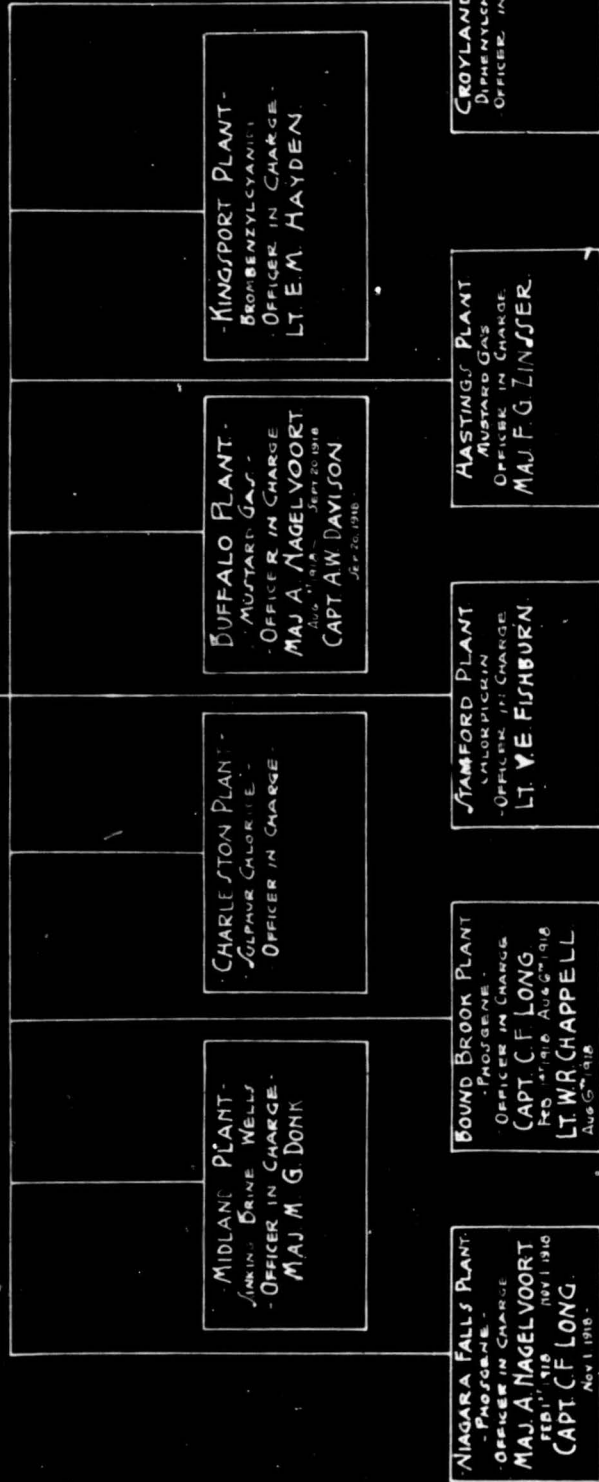
MAJ W L EVANS

ORGANIZATION CHART '4

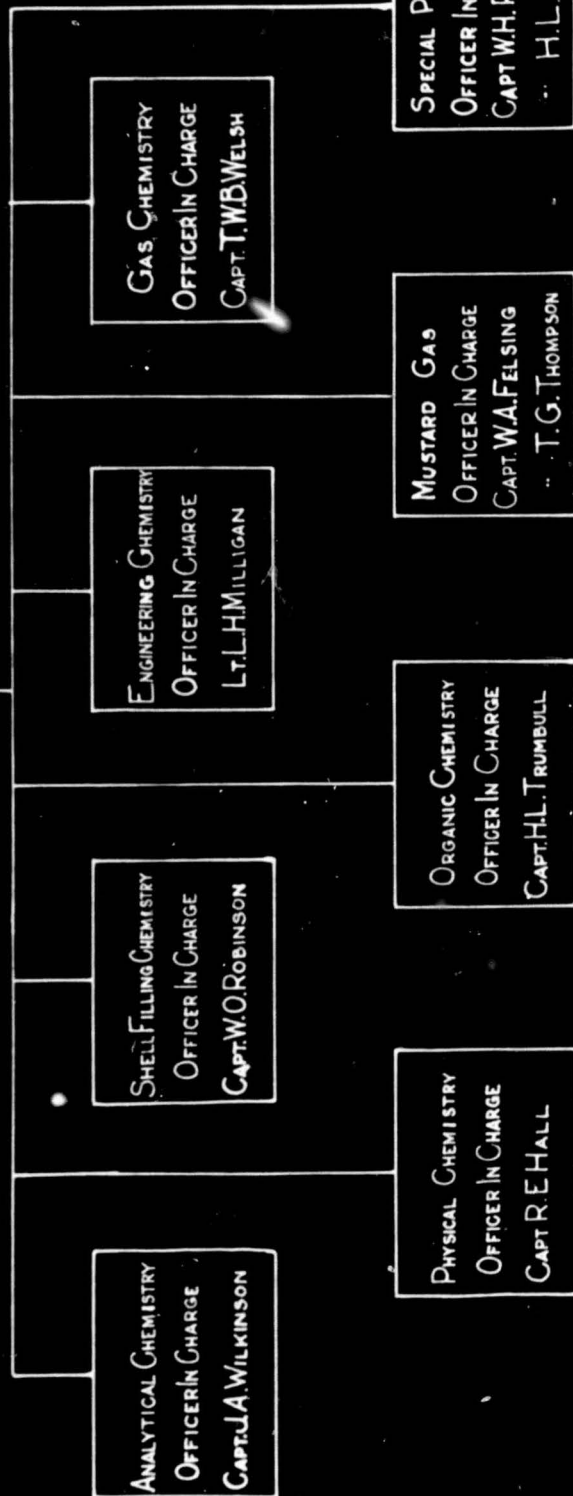


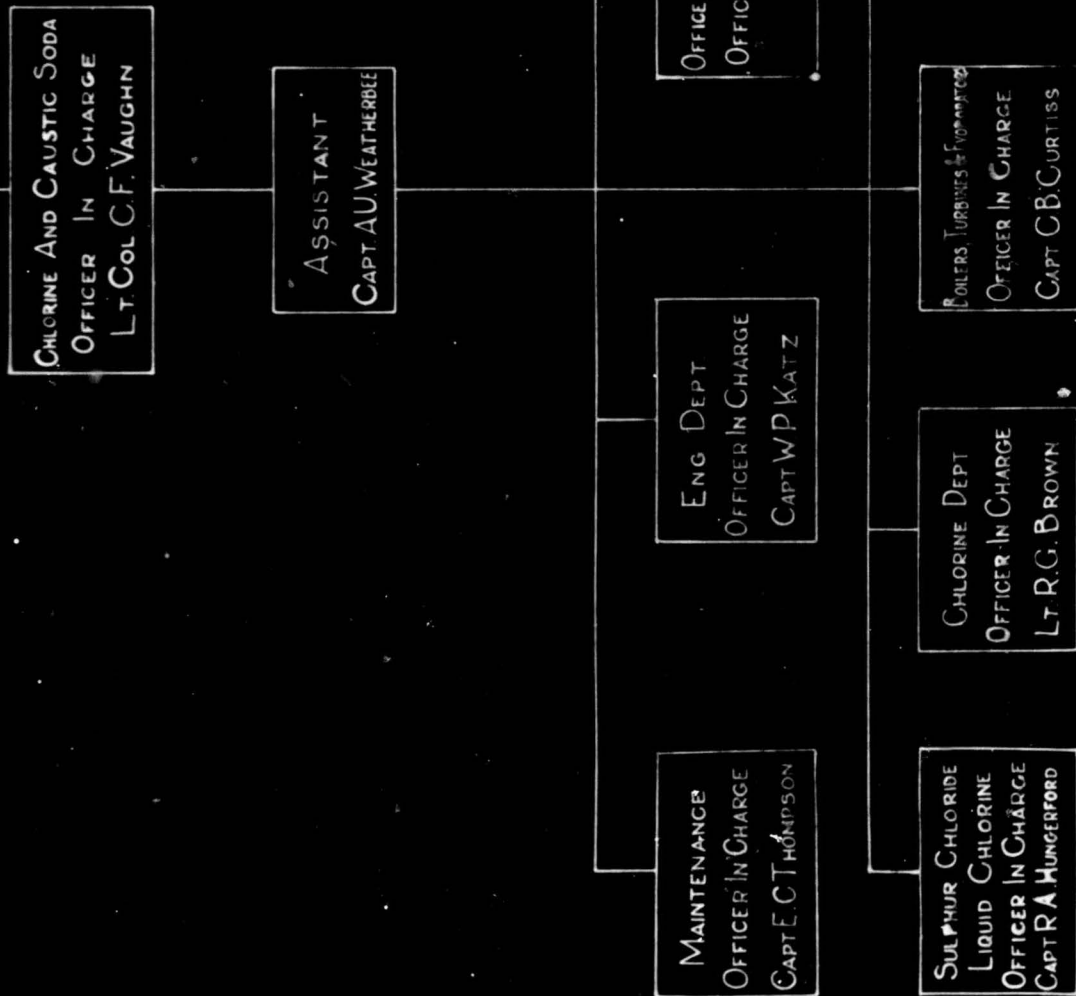
OUTSIDE PLANTS
OFFICER IN CHARGE
LT COL W^o McPHERSON

ASSISTANTS
MAJ E E FREE
MAJ C R WRAITH
CAPT D RUE



CHEMICAL LABORATORY
OFFICER IN CHARGE
MAJ W.L. EVANS





ORGANIZATION CHART '8

- FILLING PLANT SECTION
OFFICER IN CHARGE
LT COL L M CHAMBERLAIN
MAJOR F W MAGN
UNT 1910

MILITARY ORGANIZATION
OFFICER IN CHARGE
CAPT CHAS H PEARCE

ENGINEERING &
CONSTRUCTION
MAJ T M CHAMBERLAIN
MAJ E B VAN KUREN

ADMINISTRATION
MAJ ARTHUR M HERITAGE

ORDNANCE STORES
CAPT HAROLD C SHARPE

SHELL DUMPS
CAPT B F GILL

OPERATING DEPT
MAJ F W MACK
ACTING CAPT ALFRED JODLES

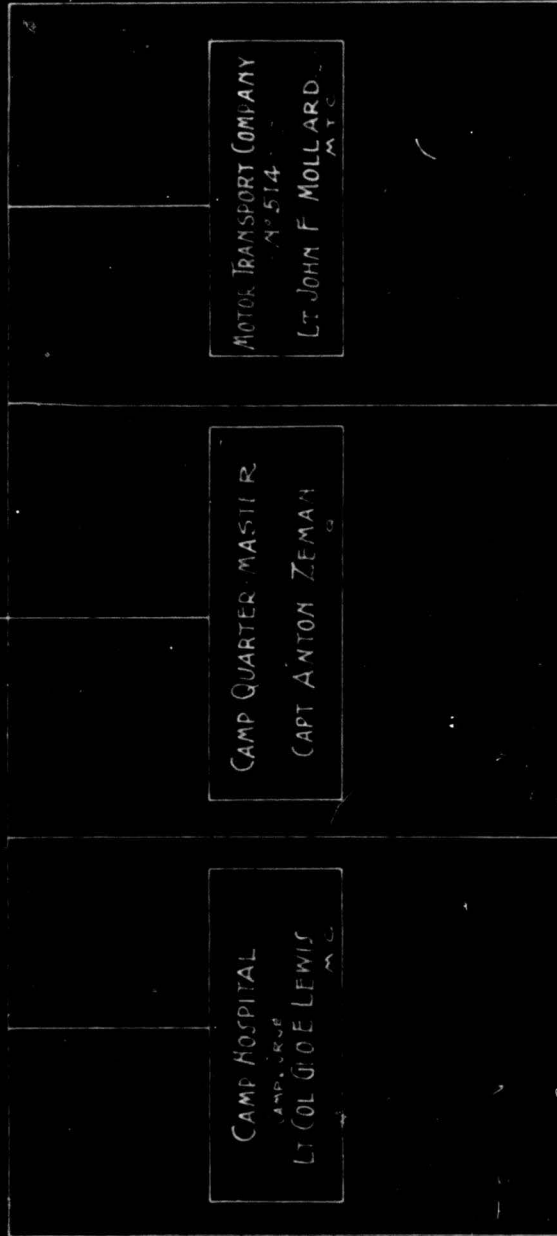
- FILLING PLANT NO. 1
LT REINHART RAHN

- FILLING PLANT
FOR 155 MM SHELL
CAPT LAURENCE L BEERE

- FILLING PLANT
FOR 75 MM SHELL
CAPT GEORGE F HILL

ORGANIZATION CHART

POST ADJUTANT
MAJOR FRANK J. WAGNER
CWS USA



CAMP HOSPITAL
CAMP COOK
LT COL GLOE LEWIS
MTC

CAMP QUARTER MASTER
CAPT ANTON ZEMAN
C

MOTOR TRANSPORT COMPANY
MTC 514
LT JOHN F. MOLLARD
MTC

1ST BATTALION
COMMANDING OFFICER
CAPT THOMAS F. McGOVERN
CWS USA

2ND BATTALION
COMMANDING OFFICER
MAJOR FRANK W. MACK
CWS USA

3RD BATTALION
COMMANDING OFFICER
MAJOR DANA J. DEMOREST
CWS USA

4TH BATTALION
COMMANDING OFFICER
LT COL CHARLES F. VAUGHN
CWS USA

I N D E X

- Aberdeen Proving Ground, 12, 13, App. 7
- Alcohol, 44, 77, 78
- American Synthetic Color Company, 10, 12, 15, 24, 56, App. 8
- Arsenicals, 65, 66, App. 2, 5

- Barracks, 26, 54, 55,
- Benzyl Chloride, 64, 77, 78
- Bleach, 10, 17, 77, 78
- Bombs, Incendiary, 59, 76
- Boosters, 28, 30, 49, 57, 58, 70, 71, 76, 79
- Bound Brook Plant, 21, 22, 24, 25, 57, App. 8, 12,
- Brombenzylcyanide
 - manufacture of, 64, 65, 77, App. 5
 - production of, 65, 74
 - properties of, App. 2
- Bromine, 38, 39, 64, 77, 78
- Buffalo Plant for Manufacture
 - of mustard gas, 49, App. 5
- Bureau of Mines
 - research work assigned to, 3
 - study of commercial methods by, 6, 7, 10, 40

- Carbon dioxide for production of
 - carbon monoxide, 19, 20
- Casualties, 62, 68, 69
- Charleston Plant, 26, App. 12
- Chemical Laboratory, 30, 31,
- Chlorine
 - description of Edgewood Plant, 34, 35, 36
 - Edgewood Plant decided upon, 34
 - method for increasing supply, 32, 33
 - operation of Edgewood Plant for, 36, 37
 - overseas shipment in bulk, 57, 58, 74
 - properties of, App. 2
 - supply at beginning of war, 31, 32
- Chlorpicrin
 - contracts for, 11, 12
 - development of large-scale manufacture, 10, 11
 - Edgewood Plant, 15, 16, 17,
 - laboratory preparation, 10,
 - number of shell filled with, 76
 - overseas shipment in bulk, 58, 74
 - producing capacity, 55, 56, 74
 - production of, 17, 55, 56, 74,
 - properties of, App. 1
 - selected for use, 7
 - Stamford Plant, 12, 18, 24, 56, 57, App. 4, 8, 12
- Commercial Research Company, 40, 41
- Construction
 - carried on by Construction
 - Division, 61, 62

during the winter of 1917-18, 26, 27
type of, 27, 30, 35, 36, 37, 44, 54, 55, 58
Containers, 69, 70
Croyland Plant 66, App. 5

D. M., 66, 67, App. 2
Diphenylchlorarsine, 65, 66, App. 2, 5
Dow Chemical Company, 25, 33, 39, App. 4, 8
Drop Bombs, 59, 76

Edgewood Arsenal

administration of, 4, 23
barracks constructed, 54
casualties at, 68, 69
character of labor, 52, 53, 54
construction at, 13, 14, 16, 17, 54, 55, 61, 62, 63
epidemic at, 51
extent of construction at, 61
hospital facilities at, 62, 63, 68
list of chemical plants composing, App. 4
military organization, 53, 54
name selected, 13, 23
organization of, App. 13-21, incl.
personnel at, 53
preparation for shut-down, 79, 80
provisions for diversion of personnel, 55
ready for operation, 27
selection of site, 12, 13
transferred to Chemical Warfare Service, 24
water supply system, 26, 61, 62
Ethylene, 40, 41, 42, 43, 44

Filling Plant

capacity of plant #1, 29
construction begun, 14
construction of
 Plants #2 and #3, 58
 plant for drop bombs, 59, 60
 plant for grenades, 59
 plant for smoke shell, 59
description of, 27
description of process of filling
 shell in, 27, 28, 29
operation begun, 60
plans for Plant #1, 4, 5, 6
ready for operation, 27, 29
site selected, 12
total capacity of, 76
total production of, 74, 75, 76

Gas - Toxic

capacity for production, 70, 71, 72
containers for shipment of, 69, 70
disposal of, 79
Government plants decided upon, 15
original plans for procurement of, 14, 15
production limited by shell and booster
 supply, 70, 71

- program, 70
 - shipment in bulk overseas, 58, 73, 74
 - total production of, 73, 74
- Gas Warfare
 - beginnings of, 1
 - problems of, 1, 2
 - status in United States of, 1
- Grenades, 59, 60, 76
- Gunpowder Reservation, 13, 14, 15, 23, App. 6, 7, 8
- Hastings Plant for manufacture of mustard gas, 50, 51, App. 5
- Hospital
 - permanent, 62, 63, App. 7
 - temporary, 26
- Kingsport Plant
 - building of, 64, 65
 - production at, 65
- Labor, 52
- Levinstein process for manufacture of mustard gas, 47, 48
- Livens drums
 - arrangements for filling, 60
 - number filled, 60, 76
 - phosgene required for filling, 75
- Magazines, storage, 63
- Midland Plant for sinking brine wells, 38, 39
- Military organization of Arsenal, 53, 54
- Mustard Gas
 - Buffalo Plant, 49, 50
 - contract with Commercial Research Company, 40, 41
 - development of sulphur monochloride method of manufacture, 41, 42, 45
 - first employed by the Germans, 39
 - Hastings Plant, 50, 51
 - Levinstein process of manufacture, 47, 48
 - number of shell filled with, 76
 - overseas shipment in bulk, 74
 - producing capacity, 74
 - production of, 48, 49, 74
 - properties of, App. 1
 - raw materials used, 44, 45, 77, 78
 - two methods of preparation, 40
 - types of reactors used in manufacture, 42, 43, 46, 47, 48
- National Aniline & Chemical Company, 49, App. 5
- Niagara Falls Plant
 - contract let, 9
 - process as carried out at, 22
 - production at, 57
- Oldbury Electro-Chemical Company, 8, 9, 18, App. 4, 8
- Organization Charts, App. 13-21, incl.
- Outside Plants, 25, 69
- Oxygen, for production of carbon monoxide, 19, 20

Personnel of Edgewood Arsenal, 53, 54

Phosgene

- Bound Brook Plant, 21,22,57
- contract for, 9
- development of large-scale manufacture, 8,9
- Edgewood Plant, 20,21,55,56
- experimental plant, 8,18,57
- laboratory preparation, 7,8
- Niagara Falls Plant, 9,22,56,57
- number of shell filled with, 76
- overseas shipment in bulk, 58,74
- producing capacity, 56,57,74
- production of, 56,57,74
- properties of, App. 1
- selection for use, 7

Phosphorus

- filling plants for, 59
- number of grenades filled with, 76
- overseas shipment in bulk, 58,74
- procurement of 67
- properties of, App. 2

Picric Acid, 10,16,17,78

Power Plant

- Bush River Plant, 37
- in connection with Filling Plant #1, 26

Raw materials

- procurement of 44,45,77,78

Salt, common 78

Shell

- slow delivery of, 30,58,71,72
- total number filled, 75 76
- weight of gas required to fill, 75

Shell Dumps, 63

Sibert, Major-General Wm. L., 24, App. 11

Stamford Plant

- contract let, 12
- operation begun, 29
- process carried out at, 11,12,18
- production at, 56
- taken over by Government, 56

Sulphur, 45,7

Sulphur monochloride

- plant at Edgewood, 45,51
- procurement of, 44,45,
- use in manufacture of mustard gas, 40

Tin Tetrachloride

- filling plant for, 59
- number of grenades filled with, 76
- procurement of, 67,74
- properties of, App. 3

Titanium tetrachloride 67,74, App. 3

Trench Warfare Section

- work assigned, 3,4

Walker, Colonel William H.
 appointed Commanding Officer, 23 App. 6,7
War Orders, copies of, App. 6-12
Water supply
 Bush River System, 26,62
 Winter's Run System, 62

Zinsser & Company, 41



DEPARTMENT OF THE ARMY
US ARMY RESEARCH, DEVELOPMENT AND ENGINEERING COMMAND
EDGEWOOD CHEMICAL BIOLOGICAL CENTER
5183 BLACKHAWK ROAD
ABERDEEN PROVING GROUND, MD 21010-5424

REPLY TO
ATTENTION OF:

APR 14 2015

RDCB-DPS-RS

MEMORANDUM THRU Director, Edgewood Chemical Biological Center (ECBC),
(RDCB-D, Mr. Joseph L. Corriveau), 5183 Blackhawk Road, Aberdeen Proving Ground,
MD 21010-5424

FOR Office of the Chief Counsel, US Army Research, Development and Engineering
Command (RDECOM), (AMSRD-CCF/Ms. Kelly Knapp), 3071 Aberdeen Boulevard,
Aberdeen Proving Ground, MD 21005-5424

SUBJECT: Operations Security/Freedom of Information Act (FOIA) Review Request

1. The purpose of this memorandum is to recommend the release of information in regard to request to RDECOM FOIA Requests FA-14-0054.
2. ECBC received the request from Ms. Kelly Knapp, the RDECOM FOIA Officer. The request originated from [REDACTED] gathering information on the Chemical Warfare Service.
3. The following documents were reviewed by Subject Matter Experts within ECBC:
 - a. History of Research at Yale University, dated 20 Nov 1918, 11 pages.
 - b. Bancroft's History of the Chemical Warfare Service in the United States, by Lt. William Bancroft; AD-495049; dated 31 May 1919, 206 pages.
 - c. A Historical Sketch of Edgewood Arsenal, by Lt. William McPherson; AD 498494; date unknown, 20 pages.
 - d. The Diary of Jet Parker; C390D1; dated Sep - Dec 1918, 26 pages.
 - e. American University Technical Reports, Bureau of Mines, War Gas Investigations (WGI) Monographs, date unknown.

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4. ECBC has determined that all of the reviewed documents are suitable for release, however, all documents must have the classification/distribution changed through the Defense Technical Information Center prior to any release.

5. The point of contact is Mr. Ronald L. Stafford, ECBC Security Manager, (410) 436-1999 or ronald.l.stafford.civ@mail.mil.



RONALD L. STAFFORD
Security Manager